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PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
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GENESIS OF ORE DEPOSITS.

By George J. Bancroft

Read at the Meeting of the Society, March 4, 1911.

The study of the genesis of ore deposits is one of the most facinating studies connected with mining. Its facination is no doubt augmented by the fact that we have so little direct knowledge bearing on the subject. At the present time almost all of the theories of ore genesis are merely tentative hypotheses, advancing simply to aid in gaining more definite knowledge, rather than the final laws established by enduring facts. It is this tantalizing haze of the unknown which adds to the charm of studying ore deposits and spurs one on to attempt to add to the reclaimed area of science one small tract, at least, of the great desert of the unknown.

To my mind a theory is not at all a satisfactory one unless it starts somewhere, ends somewhere, and presents a logical sequence of progress from the beginning to the end. Hence, in briefing my gleanings from the field of the study of ore deposits I shall endeavor to present only such theories as have the above characteristics. Moreover, as this is to be a very short paper, I will make no attempt to give the history of my ideas, nor shall I hesitate to borrow part of one man's theory and to attach it to another's, and then mayhap add a piece of my own if by so doing I can present a theory which begins somewhere, ends somewhere, and has a logical sequence of progression, nor will I, in this short paper, try to make any defense or argument for or against any theory. I will simply present the theories which appeal to me, and my readers will naturally exercise the same discretion and accept what appeals to them and reject what does not.

I shall endeavor so far as possible to avoid the use of that foolish system of nomenclature, which besets our science of mineralogy and stick to simple words. There are, however, two or three technical words which it is easier to use than walk around, namely:

Syngenetic—which means "born to gether with," and signifies an ore deposit which was formed at the same time and by the same agencies as the country rock.

Epigentic—which means "born upon" and signifies an ore deposit formed after the country rock was in place.

Metasomatic Replacement—which means the replacement in whole or in part of the crystals of the country rock by the salts of a salt bearing solution.

The first question one naturally asks when studying the formation of ore deposits is—where did the metal originally come from? We see that the great majority of the surface rocks are either barren or extremely lean in metal values, while workable ore deposits of any kind are few and far between, and such as there are, we observe, are nearly always associated directly or indirectly with eruptive rocks. To my mind the most plausable explanation of the original source of the useful metals is that it came from the Barysphere. Physicists and astronomers have weighed the earth and found it not "wanting" but overweight. Chamberlin and Salisbury in their treatise on geology give the specific gravity of the entire earth as 5·57, while the average specific gravity of the lithosphere is given as 2·7. It is very evident that the center of the earth is much more dense than the exterior. While it is no doubt true that the material near the center is greatly compressed by the pressure of the super-incumbent masses, still we have no reason to believe that the compression of the rocks *alone* is sufficient to account for the great specific gravity of the earth, and it is far more logical to assume that the central materials themselves are heavier.

The nebular theory of the formation of the earth is as well accepted as any theory on the subject, and while this theory does not necessarily involve a molten condition of the earth, yet it does involve a transition stage of incoherency when the earth was neither nebular nor solid, in which period the heavier particles would naturally gravitate towards the center, while the lighter ones remained on the outside.

We have no reason to suppose that the interior of the earth contains elements foreign to the surface, so I think it a fair assumption that there is a so called "barysphere," composed very largely of those heavier elements which we have to a limited extent on the surface. The analysis of meteors gives collateral evidence in support of this view. Meteors are supposed to be similar to the original units that formed the earth, and they contain much greater percentages of the heavier metals than the rocks of the lithosphere.

Looking now at the matter from another angle, we see that the great majority of our mineral deposits are associated with eruptive rocks, but on the other hand all eruptive rocks are not associated with ore deposits. The inference is plain, I think, that those eruptions which were sufficiently deep seated to disturb the barysphere produced ore deposits, while eruptions arising from shallower depths did not.

The metaliferous deposits which are not associated with eruptive rocks from a very small group, and, even then, many of them are secondary deposits whose primary source was eruptive rock. Thus, placer deposits of gold and tin are nearly always the secondary concentration of eroded deposits, which in turn were associated with eruptive rocks. Some iron deposits also are nature's concentrates from the erosion pulp of granitic areas, but the iron-bearing granite is under suspicion at least of being an eruptive in many cases. Probably the bog-iron and bog-manganese deposits are as far removed as any class of ore deposits from an eruptive parent, and yet in this class, if we follow back the lineage a geological generation or two, we are very apt to come again to eruptive rocks.

So, I think that, after delving into the formation of the earth and finding at least reasonable evidence of a barysphere, composed largely of the heavier metals, the next logical deduction is that the metals reached the surface through eruptive action. This leads us to a consideration of eruptions and eruptive rocks.

Just what causes eruptions is not as yet fully understood. It is fairly well accepted nowadays that the earth is solid to the core. Eruptions then must be due to local conditions. A great many plausible theories have been advanced to explain volcanoes. These theories involve chemical reactions or residual molten reservoirs or local release of pressure or local intensified pressure due to crustal movements, etc., etc.

It does not make any material difference in the logical chain of our thought which theory is adopted to explain eruptions and for the sake of brevity I will not rehearse any of them.

Eruptive rocks, as they issue from the earth in a molten state, are not at all like molten slag or "dry melts." The magma of an eruptive is a curious mixture of molten rock, sulphur, water-gas, chlorine and various other gases. There is abundant evidence to show that magmas flow from the earth in a molten condition at temperatures that would not soften the same rock, once it has solidified. I have seen lava flowing down the side of Vesuvius which was hardly a dull red heat. I have also put blocks of lava in the assay muffle and know that it will not melt at a bright red heat. Not only does a magma differ from molten slag in the temperature of flowage, but in the process of cooling it exhibits many peculiarities. In fact, it is the processes attending the cooling of magmas to which we trace the majority of ore deposits.

I will adopt the following classification of ore deposits, looking at them from a purely genetic standpoint:

First—Deposits which are part of the original magma;

Second—Deposits in fissures, cavities or porous rocks resulting from emanations from the magma;

Third—Deposits resulting from the leaching and reconcentration by meteoric waters of either of the first two classes;

Fourth—Deposits resulting from the erosion and reconcentration of either or all of the first three classes;

Fifth—Deposits resulting from concentrations of metal from non-eruptive rocks.

First—Deposits which are part of the original magma. I do not mean to include in this class veins in eruptive rock which may have been enriched by emanations from the same rock, but only such deposits as are part and parcel of the original rock, that is, are syngenetic.

For some reason, which I am free to say I do not understand, magmas, in cooling, disregard the laws of gravity and form segregations of their various constituents, quite at variance with the earth's pull. Thus, in the case of the Mackinaw nickel mine at Monte Cristo, Washington, there is a large dike of nickel bearing peridotite penetrating a country of quartenary slate and shale. Along both contacts of the dike are deposits of nickel ore. The deposits are about eight times as rich in nickel as the rest of the dike, yet they are part and parcel of the dike. So far as I know they are not on veins or fissures and can be explained only on the theory that in cooling there was a segregation and concentration of the materials of the dike.

Eruptive rocks which are sufficiently rich to pay to work the entire mass of the dike or stock are extremely rare. Most "porphyry" mines are the product of magmatic segregation, secondary enrichment, or both. There are, however, three tin mines one hundred and twenty miles northwest of Johannesburg, South Africa, which are working on pipes of greenstone in a granite formation and milling the entire pipe. These pipes are from 10 to 20 feet in diameter. It is likely, however, that part of the metal is epigenetic in character.

The great low grade copper mines at Ely, Nevada, and Bingham, Utah, are, I think, generally recognized as deposits of magmatic segregations, augmented somewhat by secondary enrichment. Although they are very low grade, yet the mass of the parent eruptives are much lower grade and not at all workable.

Among the well known ore deposits which have been classed as magmatic segregations may be mentioned the famous iron deposits of the Urals, Russia, (1) of which the Vysokaya Gora is the most prominent; the magnetite deposits of Taberg and Routivare, Sweden; (2) the Etta Knob tin deposit (3) of the Black Hills, South Dakota; the Norwegian nickel deposits (4) ; the nickel deposit of Varallo, Italy (5) ; some of the magnetite deposits of Puget Sound, Texada Island, etc.

Second—Deposits in fissures, cavities or porous rocks resulting from emanations from the magma, ie., epigenetic.

This class covers the great majority of the ore bodies with which the average mining engineer has to deal, and it would be impossible at this time to follow out all the ramifications which pertain to the study of the genesis of this class of deposits.

That ore deposits in veins were formed by emanations resulting from eruptive action has been recognized by the more experienced students of the subject for many years, but the puzzling thing to my mind, for some time may be voiced by the question—Why should the metals leave the eruptive rocks? Granting that the metals reached the surface from the barysphere by means of eruption I could discover no logical reason why the metals should not stay in the eruptives; and yet it is a matter of practical every day experience that the dikes of eruptive rock, are generally very lean, while the valuable ore deposits are found in near-by veins, cavities or zones of crushed or porous rock.

I finally arrived at a plausible explanation of this phenomena through the study of chlorine and its reactions at various temperatures upon the metals and rock'making minerals. The other halogens no doubt play an important part also, but they are present in less quantities and I am not familiar with their reactions.

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(1) R. Beck, Nature of Ore Deposits, p. 17.

(2) R. Beck, Nature of Ore Deposits, p. 21.

(3) W. P. Blake, Trans. Am. Min. Engr's 1885, Vol. XIII, p. 691.

(4) J. H. L. Vogt, 'Nick. forekomster og nick. Prod.' Geol. fören förh 1892.

(5) R. Beck, Nature of Ore Deposits, p. 39.

Mr. Francis Church Lincoln, working with Prof. J. F. Kemp of Columbia University, has compiled a very complete list of all the available analyses of volcanic emanations (Economic Geology Vol. II, No. 3), and his conclusions are as follows: "Magmatic emanations which are expelled as gases and vapors become at the ordinary temperature of the earth's surface, solids, liquids and gases. The principal gases are carbon dioxide, methane, hydrogen, hydrochloric acid, hydrogen sulphide, sulphur dioxide, nitrogen and oxygen, with less carbon monoxide and ethane and a very little hydroflouric, hydriodic and hydrobromic acids. Water is the only important liquid, and it makes up a large percentage of the total emanation. The solids are chiefly chlorides and sulphates of the alkaline earths and of iron, together with a much smaller quantity of matals and mineralizers."

T. Wolf found that near the crater of Cotopaxi the fumes were mostly of hydrochloric acid with some free chlorine, while at the lower levels hydrogen sulphide was found with a trace of sulphur dioxide. (1)

Sainte-Claire Deville found chlorides of iron and copper in a fumarole of Vesuvius. (2)

R. Bunsen found various metallic chlorides in the sublimates around fumaroles of Mt. Hecla in Iceland. (3)

A characteristic of volcanic emanations is, that chlorine is found either free or as the chloride of the metals, or as hydrochloric acid, while a characteristic of hot mineral springs is that the water contains large quantities of the chlorides of sodium and potassium.

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(1) Neues Jarbuch fur Mineralogie, Geologie und Palaeontologie, p. 163 (1878).

(2) Bulletin de la Société Géologique de France, Second Series, Vol. XIII, p. 606. (1855-56).

(3) Annales de Chimie et de Physique, Third Series, Vol. XXXVIII, p. 215 (1853).

As pointed out in my paper before the New York meeting of the American Institute of Mining Engineers, the chlorine would be in combination with the heavier metals, and would not break up the silicates, at temperatures ranging from 150 C to 1100C (atmospheric pressure), and this range covers the temperature of the ordinary magmas. Moreover, the metallic chlorides are all volatile at high temperature. Thus we have a condition which logically explains the tendency of the metals to leave the parent eruptive and precipitate in nearby veins. The metals being in the condition of gaseous salts would tend to burst out from the magma as horizons of lower pressure were reached and seek escape through crevices, veins, crushed zones, porous strata or open channels. These gaseous emanations would sooner or later be cooled to the point of liquification. In case this happened short of the atmosphere there would result a hot aqueous solution containing metallic chlorides, sulphur, hydrogen sulphide and the various other elements and compounds of a magmatic emanation.

The United States Geological Survey has conducted a great number of experiments on the reactions between acid metallic salts and the common rock forming silicates, such as orthoclase, augite, amphibole, etc., etc., and the engineer in charge of this work, Mr. Eugene Sullivan, uses these words in the summary: (Bulletin No. 312). "The natural silicates precipitate the metals from solutions of salts, while at the same time the bases of the silicates are dissolved in quantities nearly equivalent to the precipitated metals. The bases most commonly replacing the metals in these processes are potassium, sodium, magnesium and calcium."

Thus it will readily be seen that the magmatic emanation would, as soon as condensation takes place, begin reactions with the wall rocks of its conduit. Some rocks are no doubt acted upon more readily than others. A very silicious sandstone would be the least likely to precipitate metals, and it is well known that there are very few important metallic deposits in sandstone. The Neglected mine in the La Platas, Colorado, is a vein traversing red sandstone and porphyry beds. The ore is almost entirely in the porphyry beds, the sandstone horizons being barren. On the other had CaO would be one of the most active precipitants, and it is fair to assume, I think, that where hot eruptives penetrate limestone beds, that the lime in immediate contact with the eruptive would be calcined to Ca O. Thus porphyry-lime contacts are notoriously likely places for the occurrence of ore bodies, as at Globe, Arizona; Bisbee, Arizona; Cananea, Mexico; Leadville, Colorado; Cortez, Nevada; etc., etc. Limestone, itself, is a precipitant but not nearly so active as Ca O. Other rocks such as granites, schists, gneiss, and the various porphyries nearly all have feldspars or other silicates which would be more or less readily acted upon by the magmatic solutions.

A study of magmatic springs, which we may consider the liquified volcanic gases, mixed with some meteoric water, and changed by passage through the rocks, shows on the average an abundance of chlorides of sodium and potassium, CO_2 and H_2 S, but no metallic chlorides, so I think that the inference is plain that the volcanic emanations reacted as outlined above with the potassium and sodium silicates somewhere in the underground passages.

Alfred C. Lane, State Geologist of Michigan, has worked out much the same theory to account for the great iron deposits of Michigan. In the Journal of the Canadian Inst., Vol. XII, p. 19, he says: "Now we know that Chlorine and Chloride of Iron are attendant on many volcanoes and volcanic eruptions so that we should certainly keep a place for chlorides among the possible salts.

We have simply to imagine then, according to Leith's theory, that the waters leaching the iron from the basic rocks found their way into basins which also received the waters of rivers containing alkali carbonates or silicates, just such waters as come off the Laurentian Highlands in the Ottawa River today, as the recent analysis from R. A. Daly, which I cite above shows."

Mr. Lane then goes on to give the chemical reactions which would occur, showing that either ferrous or ferric chloride and sodium silicate would result in ferrous oxide, common salt and silica. If the precipitation took place in shallow oxidized waters it is probable that the sulphur fumes which are always present in volcanic emanations would not attack the ferrous oxide; while if the precipitation took place in a vein removed from atmospheric influences the oxide would be at once attacked by the H_2 S and converted to a sulphide. This reasoning agrees with the facts as we find them. It is agreed, I think, that the Michigan iron ores were formed on the surface, and they are oxides; while the primary deposits in veins are nearly always sulphides.

Thus it will be seen that a little further study of fresh volcanic emanations and their reactions with the rocks of the lithosphere will probably clear up all doubts as to the genesis of this class of deposits.

Carbonaceous matter will precipitate gold and gold only from a chloride solution, and this may account for the many deposits of very pure gold in connection with carbonaceous formations, as the specimen gold mines in the carbonaceous shale of Farncum Hill, Summit County, Colorado, or the famous gold mines of Ballarat, Australia, where the ore shoots follow a narrow carbonaceous cross vein called the "indicator."

The variety of forms which deposits of this class may assume is infinite. There are, however, certain well known types or classes of which it is well to take notice.

(a) There is the simple fissure vein, containing ore shoots. The ore shoots are generally longer vertically than horizontally, and often have a pitch. All the ore shoots in a group of closely related veins will often have the same pitch, so it is evident that the pitch was determined in some manner by the mode of genesis.

It has been somewhat generally accepted that ore shoots represent channels of flow. There are, however, some objections to the acceptance of this theory. For instance, some ore shoots pinch out at the bottom and there is not even a vein below in the direction from which the flow apparently came according to this hypothesis.

It occurs to me that ore shoots may represent zones favorable to precipitation, even where there is no change in the country rock accompanying the ore shoot. To take a very simple case, let us suppose a vein and dike crossing each other. Some of the emanations from the dike find a vent through the vein. As the emanations or solutions from the dike get further away from the source of heat, a zone will be reached at which the temperature will be very favorable for precipitation. This zone would then be marked by an ore shoot. It might be at right angles, or at any other angle to the direction of flow. Moreover a certain temperature zone might be favorable to the precipitation of a certain group of metals while another temperature zone would be favorable to an other group of metals. In such event ore shoots in the same vein would differ one from the other, and it is well known that such is often the case.

That ore shoots generally occupy places in the vein where there are more or less open channels is a fact well known, and this, no doubt, has led to the belief that ore shoots followed the more open channels. That an open channel would be favorable to the formation of an ore body cannot be denied, but with our present knowledge of the formation of ore shoots it seems to me just as reasonable to suppose that the ore shoot formed the channels as that the channel formed the ore shoot. Wherever the magmatic emanations began to react with the country rock there would naturally be formed a more open place, because in addition to chemical action between metallic chlorides and the feldspars there would without doubt be many other reactions tending to break up and leach away the silicates, leaving behind only the silica or quartz. For instance, Co_2 is a common constituent of magmatic emanations and it will act on many of the silicates, taking their basis into solution.

This matter of the pitch and habit of ore shoots is perhaps the most important point where our theorizing touches the practical working of mines and from a practical standpoint it is the gaining of knowledge of this important matter which, to a large extent, justifies the study and research into this fascinating subject. When we arrive at the point where we can say with a fair degree of certainty just how a given ore shoot was formed, we can also say, with a fair degree of probability, where a kindred one is likely to be found.

Very good examples of fissure veins containing ore shoots may be seen in Gilpin County and Clear Creek County, Colorado. In this locality, also, neighboring veins generally show a uniform pitch of the ore shoots.

(b) A large class of ore bodies are found along contacts between eruptive and other rocks. In some cases the deposit will be mostly on the eruptive side of the contact and some times on the other. I think contact deposits are less likely to lie in distinct ore shoots than is the case in veins, but there are some notable cases of very continuous contact shoots; as at Leadville in the porphyry contact. As a rule contact deposits are irregular pockets or deposits. It frequently happens, however, that the pockets will lie along certain horizons or zones, as at Bisbee, Arizona, where the contact deposits consist of a string of pockets of great size, extending along a certain geological horizon for several miles.

Many veins occupy the same fissures as that occupied by a dike without apparently being in any way related to the dike. In such cases it is supposed that the dike was cold and its habitat simply presented a line of weakness when a subsequent eruption started mineralizing agencies.

(c) A very important class of ore deposits consist of anticlinal folds. The folding of the rocks has shattered the more brittle strata and thereby provided channels for the circulation of underground waters.

The most beautiful and noted of this class are the saddle reefs at Bendigo, Australia. La Trinidad and Nacozari, Sonora, likewise have been determined to be anticlinal deposits.

(d) Impregnation Deposits.—This class is so varied that it would be impossible to cover the field in this paper. An old river channel, a porous stratum, or a crushed zone may form the habitat of an ore body and its outline may be as irregular as that of a clinker.

(e) Deposits in Open Cavities.—In the quartzite at Ouray, Colorado, and in the limstones of some of the Missouri zinc-lead fields are found more or less open caves containing beds of ore. Similar deposits occur elsewhere, but they are not a very important class, and there is some question in regard to the Missouri ores, at least, as to whether they are of primary or secondary origin.

We come now to the third group in our general classification, namely: Ore bodies resulting from the leaching and reconcentration by meteoric waters of either of the first two classes. In this group are deposits of "secondary enrichment" which are formed by surface waters percolating down through a mineralized vein, dissolving the metals in the superficial zone, and precipitating them in the vein below in conjunction with the original minerals.

This action is particularly pronounced in copper and zinc ore bodies, because these two metals form soluble salts in the process of oxidation. The zone of secondary enrichment is often the only workable part of a copper mine. Chalcocite is the characteristic secondary ore of copper and calamine of zinc.

Iron ores also have a tendency to form deposits of secondary enrichment. When speaking of iron ores I refer to the oxides of iron because the sulphides of iron are not valuable as iron ores.

Alfred C. Lane, geologist of Michigan, is authority for (Journal Canadian Inst. Voy. XII, p. 19), the statement that alkaline waters attack the iron silicates and that the iron may be precipitated by oxidation. Thus alkaline waters percolating through a bed of iron ore would tend to concentrate the ore on the side of issue.

In a similar manner ore bodies of migration are formed. If the metal which has been leached from an ore body is not precipitated in another part of that same ore body it may be precipitated outside.

In this way bog-iron and bog-manganese are formed, the proximate source of which may be epigenetic deposits of iron sulphide or oxide, or it may be syngenetic deposits, either sulphide or oxide. As examples I will mention, first, the iron deposits at the head of Hall Valley and Geneva Gulch, Colorado. In this case the iron apparently resulted from the leaching of large porphyry dikes containing iron pyrites. The waters gathered in veins and issued to the surface in springs along the bottoms of the gulches. Here the iron has been precipitated in surface beds of very considerable extent. The Colorado Fuel & Iron Company owns the larger beds.

Second, I will mention the lake ores of Finland and Sweden. Here, according to Beck (Nature of Ore Deposits, p. 99), the iron has been leached from granites and other iron bearing rocks, and it is supposed that the humus acids were active in the leaching. The ore is precipitated in lakes or quiet pools and it is thought that a certain water plant, called the Iron Algae, is instrumental in the precipitation. The action forming these lake ores is going on at the present day so fast that certain lakes can be mined intermittently. The ore is very pure iron ore and a layer about eight inches thick is formed in some localities every twenty years.

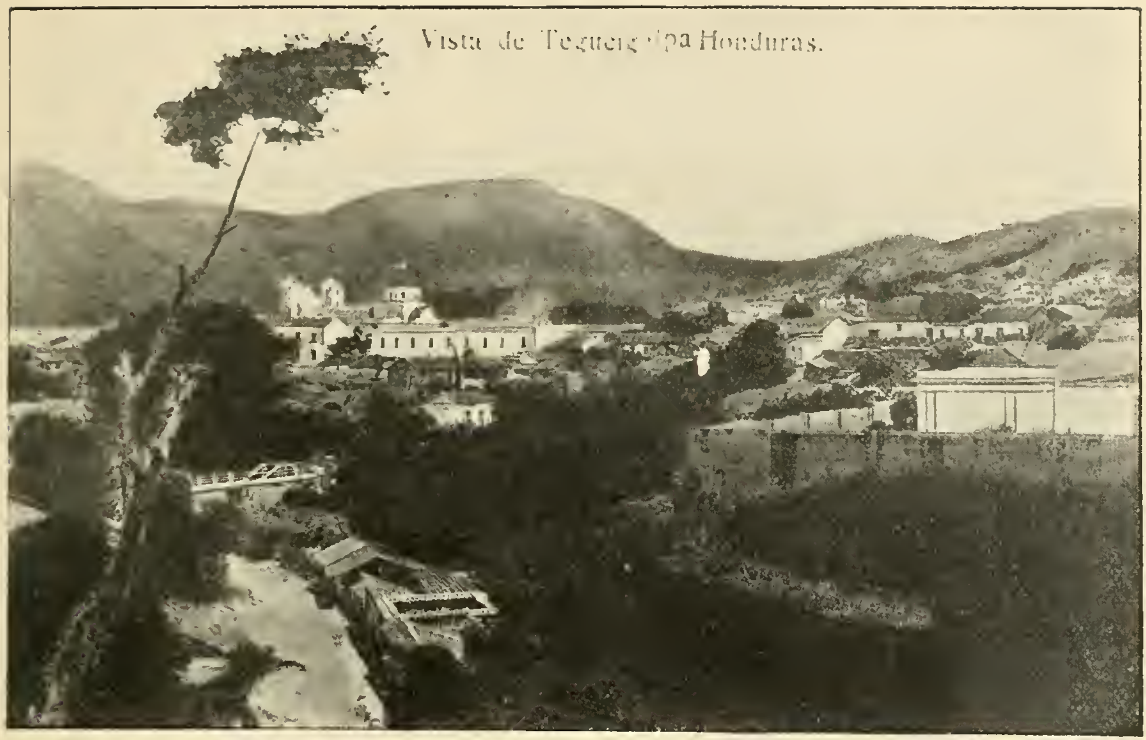
Fourth class: Deposits resulting from the erosion and reconcentration of either or all of the first three classes.

Placer deposits represent nearly all of this group. There are, no doubt, placer deposits formed ages ago which have been solidified into rock and buried under later rocks. The "Deep Leads" of California are supposed by many to have been formed in this way. For a long time the Banket at Johannesburg, S. A. was supposed to be an ancient beach placer similar to the present day one at Nome, Alaska, but I believe the latest students regard it as a porous stratum that offered a convenient conduit for magmatic solutions. The "Deep Leads" of California are ancient river channels buried under eruptive overflows. Some of the gold found in them was no doubt placed there by processes of erosion and mechanical concentration, but the evidence is fairly good that the coarse gravel of the buried stream beds offered convenient channels for the circulation of magmatic solutions and to the placer gold was added auriferous pyrites from the solutions. Thus these "Deep Leads" are not only a good example of ores of the fourth class, but represent as well how an ore body may be the result of two or more processes.

The principal placer deposits are worked for gold or stream tin, the black sands being sometimes worked, as a by-product, for various other metals.

Most gold placer deposits are formed by the erosion of areas containing gold veins and the mechanical concentration of the gold in the stream beds. As erosion progresses a portion of a stream bed may be left high and dry on the side of the valley. Such deposits are called bench placers. Good examples of gold placers, both valley and bench, may be seen at Breckenridge, Colorado.

Fifth class: Deposits resulting from concentrations of metal from non-eruptive rocks. As previously stated, I think this class is not a very large or important one. I have never seen an important ore body of any kind which did not give good evidence of a direct or indirect eruptive origin. Nevertheless it is conceivable that a concentration may occur from non-eruptive rocks which would be of industrial importance. The only example I can give is the beds of black sand in the channel of Bear Creek, Jefferson County, Colorado. I am very familiar with the drainage basin of Bear Creek and know that there is only a very little eruptive rock in it. The country rock is quite uniformly schist and gneiss of Pre-Cambrian age, and it all contains a little iron. In excavating for the foundation of a dam, I found a very pure deposit of very heavy black sand about six inches thick. While I made no tests for iron, I think it is safe to assume that the black sand contained as much iron as some workable iron ores. If this deposit could be formed from non-eruptive rocks, it is conceivable that more important ones may also be formed from similar sources.



Capital of Honduras.

Country Home, with roof thatched with monaco palm leaves.

Ulua River at Pimienta and Army Encampment.

Government Troop at outpost of large camp.

Water-carrier.

View Along Trail, showing Cotton Tree in center, Grape Tree at right.

Carib Negroes loading lighters with bananas at Tela, Honduras.

Ceiba, Honduras.
At left of the town the first battle of the recent revolution was fought.

Transporting Supplies to San Juancito.

Honduras Railroad, U. S. Sailors on Caboose.

Trail in Lowlands.

View of San Juancito, showing pipeline which furnishes power to hydroelectric plants.

Matapalo, the vine which throttles trees in the lowlands.

A Banana Plant.

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VOL. X, pp: 17-38.

NOTES ON HONDURAS

By Rensselaer H. Toll

Read at the Meeting of the Society, April 1, 1911.

This paper is not intended as a scientific article, as might be supposed because of its presentation before this Society. Rather is it a sort of literary crazy-quilt hastily pieced together of fragments of recollection of a recent trip to Honduras.

The subject can hardly be treated in a very scientific manner, but its products, its people and its politics are matters of popular interest to us of the United States, and these Central American countries appear destined to become objects of much more interest and greater responsibility to us in the future than they have been in the past.

We have assumed the responsibility of protecting these nations from foreign powers, and have said to the world, "Hands off!" Like the dog in the manger, we have refused to allow other nations to eat of the hay, although we have not cared for it ourselves; and the time is near when other nations will demand of us that if we will not permit them to protect their own interests in Central America we shall protect them ourselves—that we shall see that these countries have a stable government and if the inhabitants will not bring about that end we shall do it for them. This is one of the problems which confronts America today, and it is not by any means to be lightly passed upon.

On this recent trip, during which a revolution was raging, the writer had an opportunity of talking with many American, European and educated native residents of this country, and one and all expressed the hope that the United States would be called upon to intervene and assume a real protectorate over Honduranian affairs. They seemed to believe that this must be done sooner or later, and the sooner the better for Honduras and the world in general.

Central America is rich and should be developed. Many foreigners would like to go there to live, and its own people desire enlightenment and improvement. They wish railroads, wagon roads, mills, schools and the other advantages of civilization; but all these things require capital, which must come from abroad. And foreign capital, owing to the highly volatile nature of Central American politics, is afraid.

It may be wondered why the inhabitants of these rich countries cannot develop their own resources; and the answer is that they have neither the capacity nor the incentive. They, too, are afraid. Whatever they may acquire in times of peace is taken from them at the first political explosion, and they are constantly discouraged and spiritless.

Under favorable conditions they are as ready to work and to learn as the masses in more enlightened countries. The masses want protection, not from foreign nations, but from their own politicians, and would welcome any government which would give them safety and a fair measure of justice.

Honduras has almost no schools, no railroads worthy the name and no cart roads except the one which President Bonilla built from Amapala to a few miles beyond Tegucigalpa; practically no fit means of transportation anywhere. Its rich mines are mostly idle, many of the various and excellent agricultural products are almost valueless; and, when the politicians will it, the poor native must go to war and bleed for the cause of the leader whose soldiers are first to find him. He has little appetite for these political wars and usually takes to the bush; but if found, and able-bodied, he is forced to "volunteer" even if it be necessary to bind his hands behind him and lead with a rope. If defeated in battle he will probably join the victorious army, for has he not been taught to stay with the Lord, and is not the Lord ever on the side of the mighty?

Honduras covers an area of but 50,000 square miles, less than half the size of the State of Colorado. Its population is estimated at 400,000, comprising 185,000 Indians, 205,000 of mixed blood, 5,000 negroes and 5,000 whites, most of whom are of Spanish descent, though a great many Americans and Europeans are scattered along the coasts, in the larger cities of the interior and through the mining regions.

GEOGRAPHY.

The coast lines of Honduras run nearly east and west. The Caribbean coast is about 400 miles long and contains many good harbors, such as Trujillo, Ceiba, Tela, Omoa and Cortez, the last named being the usual port of entry for travelers. The Pacific coast is cut off by San Salvador, leaving but sixty miles to Honduras, which, however, contains the beautiful harbor of Amapala. Both coasts are unhealthy, but the miasmic influence does not extend far inland.

As elsewhere in America, the principal rivers flow to the Atlantic. The Segovia, or Coco river, which forms most of the boundary between Honduras and Nicaragua, is about 350 miles in length, but it flows over a shallow, rocky bed and is navigable only by canoes.

The largest river entirely within the boundaries of the country is the Ulua, which flows nearly north and is formed by the confluence of the Santiago and Comayagua, with their respective tributaries, the Santa Barbara and the Sulaco. Steamers of shallow draft can ascend the Ulua as far as the mouth of the Santiago, about seventy miles by the course of the stream.

The Comayagua river rises in the mountains at the southern border of the great plain of Comayagua, more than two-thirds of the distance to the Pacific coast; and the aggregate streams of Ulua system drain about one-third of the entire territory of Honduras.

As a whole the country is very mountainous, not even the coasts being free from rugged heights, for along the Caribbean many mountains raise their proud heads above the clouds while their feet are bathed by the ocean surf. Nor are their elevations insignificant, for many peaks reach an altitude of 9,000, while in the Sulaque mountains are some which approximate 10,000 feet above the sea.

Mountainous as the country is, there are no consecutive ranges of great length, the longest being the Sierra Madre, and this splits into two parts soon after leaving Guatemala. Between the various small ranges of mountains are broad, fertile plains like that of Comayagua, which is about forty miles long from north to south and ten miles in average width; the plains of Yoro and Olancho, celebrated for the excellence of their cattle; the plains of Omoa, Sensenti and many others, all extremely picturesque and fertile.

CLIMATE.

On the northern coast the climate is hot, but in the highlands of the interior it is remarkably equable, the mean temperature ranging from 62° to 86° F., depending upon the elevation. In the interior the warmest months are April, May and June, while November, December and January are cool enough for fires.

Excepting along the northern coast from the first of January to the middle of April but little or no rain falls, but the remainder of the year is extremely wet, the average annual rainfall in the interior being about 150 inches, with 200 inches along the Caribbean coast.

However, the climate is extremely capricious, seeming to be largely dependent on local topography, and of two points but a few miles apart one may be suffering for rain while the other has heavy showers every day.

The variations of climate and temperature, combined with the marvelous fertility of the soil, adapt this remarkable country to the cultivation of the products of every zone.

HISTORY.

Ages before the discovery of Honduras by Columbus in 1502 it was inhabited by a highly civilized people, the ruins of whose structures are in evidence at numerous places today, notably at Copan, where the remains of magnificent edifices stretch for two miles along the broad Copan river in a dense forest.

Among the ruins are the walls of a great building, 624 feet in length, supposed to have been a temple. There is a plaza paved with well-squared stones; a tower or terrace with a grand stairway extending down to the river; gigantic, elaborately carved monolithic statues, and many other sculptures.

So ancient are these ruins that even at the time of the Spanish conquest the natives could give no clue regarding the identity of the builders or the time of construction. As the mode of construction and hieroglypics which adorn the many tablets are the same as found at Palenque, Yucatan and Mitla, Oaxaca, they evidently are nearly or quite contemporaneous, and many archæologists associate the builders with the builders of Babylon and Chaldea.

In 1526 Cortez took possession of the country for Spain and founded the towns of Trujillo and Caballos, now called Puerto Cortez. In 1823 Honduras entered the Central American federation, but became an independent republic in 1839 and took part in the wars and intrigues which followed one another in rapid succession until 1862. Civil strife also has retarded the development of the country and added to the misery of its inhabitants, and but short periods have passed without internal disturbance of some nature.

Among the politicians each wants to be boss, and as soon as a disgruntled one has been able to obtain a suitable following and sufficient financial backing he has started out on the trail of those who were in power. The recent revolution, which took place during the writer's trip through the country, had been in preparation for three years and had the sympathies of a large majority of the people.

Manuel Bonilla, during his term as president, had inaugurated many reforms and improvements. Realizing that the country needed means of transportation above all else, he had projected a wagon road across the country, which was completed in supurb manner from San Lorenzo to Tegucigalpa and about a dozen miles beyond. It is a broad, smooth road of easy grades, with fine masonry bridges and culverts; an excellent piece of construction. It was almost completed to the city of Comayagua when President Zelaya of Nicaragua invaded Honduras in 1907, deposed Bonilla and made Davila president.

Since then the taxes have been greatly increased, in some districts to such an extent that production became unprofitable, and the improvements made by the former president fell into disrepair. The greater portion of *el camino real* west of Tegucigalpa is now in such a state as to be impassable to carts, and the only way it is used at all is *crossways*, serving as a guide to the traveler. Whenever you cross the *camino real* you know you are on the right trail.

The first battle of the recent revolution was fought at Ceiba, January 24, 1911, and out of about 800 combatants 186 were killed. The government forces under General Guerrero were strongly intrenched about the town, with a seemingly impenetrable swamp east of them. Guerrero was killed early in the battle, and after nearly five hours' fighting his troops were defeated, having been surprised by Bonilla's troops under Lee Christmas, an American, who cut their way through the swamp.

The revolutionists were successful in practically every engagement, and after about six weeks peace was declared, President Davila resigning, and Bertran, a protege of Bonilla, was named provisional president.

The finances of the republic have always been in great disorder, owing to the continual strife and the railroad loan, and the present time is no exception.

COMMERCE.

The trade of Honduras is not great, the annual exports and imports amounting to about $3,000,000 each, nearly all with the United States.

Sugar is one of the principal articles of export, as the cane thrives in all parts of the country up to altitudes of 4,000 feet; and the same may be said of the banana and plaintain. Tobacco of the highest quality is raised in many localities. Coffee flourishes wherever cultivated, but its culture is greatly neglected. Cocoanuts abound along the northern coast.

In the interior the fruits and vegetables of the temperate zone grow luxuriantly with little or no care. Maize and Kaffir-corn are extensively raised, and Honduras rice is famous throughout this hemisphere. Capsicum, pimiento and many other spices are plentiful.

The arboreal vegetation of Honduras is unsurpassed. Mahogany, cedar, rosewood and other fine cabinet-woods abound throughout the lower country, and in the mountains are building timbers of all kinds, as well as the first three mentioned. In the interior, remote from transportation facilities, one often sees bridges and culverts made of mahogany; boats, or *cayucas*, some of them twenty-five feet in length and of four and five-foot beam, beautifully hewn of a mahogany log; the most ragged and poverty-stricken families live in mahogany houses, sitting in mahogany chairs, eating from mahogany tables, and even indulging their scrawny pigs in the luxury of a solid mahogany trough. This may seem rather incongruous, but mahogany is of no more value than any other wood in these remote districts, and has the unique advantage of being free from attack by insects.

The principal articles of commerce are bananas, rice, coffee, sugar, seisal, mahogany, cattle and hides. Some rubber and chicle are exported, also, though British Honduras is the most important source of supply of the latter delectable article.

Chicle is the dried sap of a tree much resembling the rubber tree, and is used for manufacturing chewing gum, which is a very simple process, the chicle merely being sweetened and flavored and molded to the desired shape. This tree also bears a fruit which resembles a large musk-melon with the lower end pointed. Its meat is darker, however; very soft and sweet, and tastes much like chocolate custard.

Rubber, chocolate, cotton and many other products would no doubt be important articles of export under more favorable conditions of politics and transportation; and other profitable industries would be founded.

For instance, there is a species of yucca which has a root resembling the sweet potato, from which is produced the most excellent starch known. The monaco palm bears enormous clusters of nuts about the size of a walnut, which have a smooth, white shell from which a great many of our "ivory" buttons are made. The meat tastes much like the filbert and is very oily; and a company has recently been organized to manufacture from this nut a table-oil which is said to be a very good substitute for olive-oil.

The achote tree bears pods which contain small seeds similar to that of the sumach, which is covered with an orange-colored oil substance much used for coloring butter, etc. Crushed, the seed makes a highly prized flavoring for soups.

MINING.

In mineral resources Honduras ranks high, among the metals so far discovered being gold, silver, copper, iron, lead, zinc, antimony and nickel. Kaolin, opal, aluminum, chalk, coal, asphalt and petroleum also are found in quantities which will doubtless render them all profitable under more advantageous conditions. All kinds of building stone, including marble of a fine quality suitable for statuary, are found in different parts of the republic.

Because of the inadequate transportation facilities only the precious metals can be mined profitably at the present time, and the disadvantage of civil strife and lack of roads many years ago rendered the operation of precious metal mines so unsatisfactory that there now exist throughout the country many properties which are susceptible of profitable operation.

Many of the rivers, especially those flowing into the Atlantic, contain gold in paying quantity—at least for the Indians to work; and there are several small quartz mines in operation in different parts of the country. Some of the placer mines are said to contain platinum in so appreciable an amount as to be paid for by the United States mints.

However, withal this showing of valuable metals, the only mine of importance in Honduras at the present time is the San Juancito, owned by the New York & Honduras Rosario Mining Company, with headquarters in New York. This mine is located in the Department of Tegucigalpa, about twenty miles north of the capital, on the northern slope of a steep and high mountain formed principally of andesite overlying black shale.

The main veins, the Rosario and Candelaria, strike generally east and west, dipping steeply to the north, in places being quite vertical. These veins have been worked for over thirty years and there are about thirty miles of workings, having a vertical extent of 1,800 feet. But the mine is said to be in better condition now than ever before. Within recent years important north and south veins have been developed which appear to have given the property a new lease of life.

The mine is equipped with electric haulage and a single ropeway conveys the ore to the mill, an old and very rickety affair of fifty stamps and two tube mills. The values are extracted in the cyanide plant, which comprises mechanical agitation tanks and Butters filters. The precipitate is shipped to New Jersey, as the cost is about the same as that of reduction on the ground and considerable labor is saved.

About three thousand tons per month are milled, and the annual production is close to a million ounces silver and sixteen to seventeen thousand ounces gold. About two thousand men are employed, of whom forty are Americans.

The equipment of the Rosario is constantly undergoing renewal and improvement, two very fine hydro-electric plants having been built recently; and a new mill and cyanide plant, offices, hotel, clubhouse, etc., are in course of construction on the mountainside at the level of the lower tunnel, 1,500 feet above the present townsite.

This property is connected with Tegucigalpa by a most outrageous cart road, which in the higher mountains is very muddy because of the numerous springs; and the grade in many places is over thirty per cent. As an illustration of the difficulties of operation in such a locality it may be mentioned that the cost for transportation of heavy freight from San Lorenzo, the port near Amapala, to San Juancito is five cents gold per pound, light freight costing about half as much.

Tegucigalpa practically lives off the San Juancito mine. As all the freight of the mine passes through the capital the company maintains its local office there and does considerable trading in the city, and almost the entire pay roll of the mine eventually finds its way there. If the mine should close for thirty days there would be many hungry people in Tegucigalpa, and permanent shutdown would reduce the busy city to an idle village.

MINING LAWS.

The mining laws of Honduras are very liberal. Any amount of ground may be denounced, but the usual size of a claim is 500 hectares, or 1,220 acres. By following a procedure similar to our patent proceedings a title may be secured which is equivalent to a patent in the United States. The annual tax is fifty centavos (about 20 cents gold) per hectare, and so long as the taxes are paid the title remains absolute. But should they be unpaid for a period of two years the ground reverts to the public and is open to denouncement again.

As in Mexico, there are no extralateral rights, all boundary lines being vertical. For a small consideration one may obtain a concession to prospect and locate claims over a large area, during the term of which no one else is permitted to make denouncements within the specified territory.

Upon application to the president, mining machinery and supplies may be brought into the country free of duty.

LINES OF TRAVEL.

The interior of Honduras is reached through Puerto Cortez on the north coast and Amapala on the south coast. From New Orleans the United Fruit Company operates small steamers, which make the trip to Cortez in a little more than five days, stopping at Belize, British Honduras and Barrios, Guatemala. The steamship fare is $27 each way.

From San Francisco to Amapala requires twenty-two days and costs four times as much; hence, though the trip from Amapala requires but three days over a good road, and that from the railroad at Pimienta to the capital requires six days over a fierce trail, much time and money are saved by going through Cortez. Also, by this route one may have the pleasure of riding over the most expensive piece of railroad in the world.

The steamships Rosina and Joseph Vacaya sail from New Orleans on alternate Wednesdays, and no matter which one you happen to catch you will wish you had caught the other. They have but seven staterooms and are usually crowded, and the table is miserable, although you may not notice that the first day or two on the Gulf if the weather happens to be a little rough and you are not a very good sailor.

If the traveler have time and inclination he may take one of the large, new steamers of the United Fruit Company and catch one of the smaller ones at Barrios. These vessels are of 5,000 tons burden and very comfortable, almost luxurious; and a trip on one of them is quite a delight. During the wait at Barrios you may run up to Guatemala City, the metropolis of Central America, and spend a day or two viewing this interesting old city and laying in a supply of silver jewelry and silk shawls for souvenirs.

Cortez harbor is one of the best on the Gulf. It is elliptical in shape, about nine miles in circumference, and deep enough for the largest vessels to anchor.

On the night of our arrival the United States gunboats Charleston and Marietta and the English cruiser Brilliant were at anchor near the town, while a couple of fruit steamers lay at the wharf; and the spectacle presented, with swift launches racing to and fro, the American vessels flashing messages from their foremast-heads, while the cruiser played her powerful searchlight over the bay and shore and the singing of the sailors and the music of phonographs floated over the water, was one long to be remembered.

Puerto Cortez is a straggling, crudely built town stretching along the shore for two miles. Its single street is occupied principally by the Honduras Railroad, whose terminus is the wharf at the lower end of town. At the upper end it enters the jungle, bound for La Pimienta, on the Ulua river fifty-six miles away, which distance the train usually—at least quite often—covers in about eight hours.

This little narrow-gauge road is the first installment of a transcontinental line which was projected to San Lorenzo through the valleys of the Comayagua and the Goascoran, which practically bisect Honduras, a total distance of 232 miles.

From 1867 to 1879 bonds to the value of about $30,000,000 were floated in London and Paris for the purpose of building this railroad. An English company took the contract for construction on a percentage basis and, naturally, it profited them to make the construction as costly as possible. So, between the commissions for the sale of the bonds and the padded accounts for material and labor, by the time the road had reached San Pedro the proceeds from $25,000,000 worth of bonds had been consumed; a cost of nearly $700,000 per mile. It was finally completed to the Ulua river and graded several miles beyond, but the government was bankrupt. Many of the bonds were repudiated and only the big stick of Uncle Sam, in the shape of the Monroe Doctrine, prevented England from taking charge of Honduranian affairs years ago.

Notwithstanding the enormous expenditure the construction of this railroad was wretched. For miles the rails were laid upon the bare ground without ties of any kind, being held in place by stakes driven into the earth. They soon became imbedded to such a depth that lateral movement was impossible, so the trains probably kept the track as well as they do now.

On our trip to the interior the train was somewhat late in starting, necessitating greater speed than the customary ten miles an hour. The unusual friction on the bearings soon developed a "hot box" and the delay necessary to cool the journal rendered still greater speed essential, which soon caused another "hot box." And so on.

While we were waiting patiently for the train to start after the 'steenth stop from the same cause, the conductor, who spoke a little English, happened along and shyly remarked that he supposed we knew we were on a fast train, to which the joker of our party replied that we fully appreciated that fact, but had been wondering for several hours what in the deuce it was *fast* to.

Heroically the conductor arose to the occasion and responded that it appeared to be fast to the rails, which was quite true at that time, but not for long. Soon we were rushing frantically along at the terrific speed of fifteen miles an hour, and as the train struck a particularly smooth piece of track our car suddenly sidestepped a couple of feet and went bouncing along as if it were mounted on cams instead of wheels. Passengers rushed to the doors, and one fellow jumped into a deep ditch and was plastered with mud and leaves.

I noticed, however, that most of the natives kept their seats as best they could, which I accepted as evidence that the occurrence was nothing unusual, and I hung onto mine until the train, after running about two hundred yards over the ties, came to a stop, and twenty minutes of pushing and pulling served to place the car again upon the rails and the journey continued without further accident.

For the benefit of future travelers over this road it is respectfully suggested that the management either repair the track or put steering gear on the locomotives.

But, bad as the track and cars may be, this little railroad presents many interesing features. For many miles it runs through a dense jungle of palms and other tropical foliage whose sweeping branches cast grateful shade over passing trains; while the trailing vines, covered with morning glories and flowers of strange shape and gorgeous colors, lend fragrance and magnificence to the scenery which the most carefully cultivated lawns and flower beds of our great eastern roads cannot equal.

A dozen miles from the coast the jungle frequently gives way to large, cleared pastures and *fincas,* where the luscious banana hangs from its broad-leafed stalk; and at each station cars are being loaded with this nutritious fruit.

The day before our arrival at Cortez the American and English officials had taken charge of that port and had shipped the Honduranian army out of Cortez and San Pedro and dumped it off at the end of the railroad, and when we reached that point a most interesting sight met our eyes.

On the opposite bank of the river lay the camp of the government forces, with a line of entrenchments stretched along the bank for half a mile. All the boats were moored on their side of the river; more than a thousand riflemen were in their pits and trenches ready for battle; nine machine guns and two two-pound cannon were loaded and trained upon the town and railroad, and the camp was in general readiness, if not eagerness, to cut down ruthlessly any revolutionists who might get off our train. Fortunately for us we carried no such passengers, else the delivery of this paper might have been perpetually delayed.

At La Pimienta one is obliged to take passage on a mule, and here the really tiresome portion of the journey begins, for five or six days on the hurricane deck of a Honduras mule is not the most delightful experience in the world even to a stranger, to whom the wonderful foliage, picturesque dwellings, the brilliant flora and myriads of gorgeously plumed birds present an ever-changing panorama of loveliness.

Soon the diet of tortillas, frijoles and rice, the steady grind of the saddle and the stings of numberless insects by day and by night spoil the effect of the landscapes and novelty of the environ, and by the end of the second day the screams of the vari-colored macaws flying in pairs across the sky, the chatter of monkeys in the trees, the bright plumage of the big-billed toucan and the golden-tailed *oro pendulum,* singing in melodious contralto from above its wonderful swinging nest at the end of the highest branches, have become commonplace. At the end of the second day finds the greatest interest in the application of witch-hazel to his sore muscles and iodine to his insect bites, for the bane of existence in Honduras is the ravenous nature and overwhelming numbers of the insects.

The timber tick is always present in full force, the nimble flea fills every habitation, and along the coast the mosquito and the tiny sand fly add their due portion to the sum total of human misery. But for general cussedness no other insect on earth can compare with the *garrapata,* a minute representative of the tick family, which waits in hordes at the end of every branch along the trail to drop upon the passerby, scatter over his person and bury their screw-like heads in his flesh. Against their ravages man has no protection but tobacco juice, though by keeping one's clothing saturated with this drug one may pass through the interior with a small degree of freedom from these pests.

Another very interesting insect is the *nigua,* which is almost microscopic and hence difficult to detect. The principal business of this brute is to bore into the flesh at the side of the nail, usually on the toes, and deposit its eggs, making sores similar to boils; and the only remedy is to cut out the obnoxious nester and its larvæ, often a painful operation.

OUTFIT.

For the benefit of those contemplating a trip into the interior it may be well to state that the outfit for the journey is best obtained at San Pedro—mules, mozos, and all.

With proper credentials it is often possible to rent animals at about one peso a day. Mozos, or native attendants, may be engaged at the same rate. Often, however, one must purchase animals, and a good mule costs about 200 pesos; horses, 25 to 100 pesos. A saddle-animal, a pack-animal and a mozo are required for each person, unless the party consists of more than three, in which case the proportion of pack-animals and mozos may be decreased.

The essential articles of clothing are: Light underwear, khaki suit, good water-proof hat with broad brim, high boots, and a good rain-coat always strapped to the saddle, preferably a black rubber coat, as "oil-skins" and cravenettes are slight protection against a prolonged tropical shower.

It is not advisable to carry any luggage which can be damaged by rubbing on the outlandish native pack saddles or crushed by tight binding ropes. Use heavy canvas bags or wrap in a bundle and cover with oilcloth.

It is well to lay in a small supply of canned goods and bread, for though there are places along the trail where travelers regularly spend the night, noonday finds one far from habitations and the fare at the lodging places is not exactly sumptuous.

Do not forget a small assortment of bandages, cotton, court-plaster, surgeon's plaster, vaseline, carbolic acid and witch-hazel; quinine to allay fever; iodine, potassium permanganate and potassium bisulphide for stings and bites of insects or reptiles. The writer always carries an ounce or two of aconite to ward off colds. Five or six drops of this every couple of hours when one feels a cold coming on will do no injury and is a sure preventive.

For sleeping purposes a pair of heavy blankets and a hammock or folding cot make up the equipment.

It is not a bad idea to carry a .38 caliber revolver for protection against unkindly disposed men and a means of killing game.

FUANA.

Deer are plentiful throughout the country; peccaries, tapirs, coyotes, jaguars and other animals are found in some parts of the interior; the iguana, a species of lizard which attains a length of three to four feet, is quite common, and the natives esteem its flesh a delicacy; squirrels abound through the forests; and there are ducks, geese and numerous game birds, of which one of the most common is the *chachalaka*, which resembles the wild turkey.

Along the trail one finds many strange flowers, fruits and trees to excite his interest. Orchids of many varieties cling to the branches, and depending from the latter or wrapped about their trunks, are numberless vines, the most remarkable of which is the *matapalo*, meaning "kill tree," which winds about the trunk and branches, spreads and grows together, at last literally strangling the object which has been its support. Finally the tree dies and rots away, leaving the ungrateful vine standing in its place, hollow but almost everlasting.

One of the most curious of trees is the cotton tree, which grows to a height of thirty to forty feet. When it blossoms the leaves drop off, and a strange and pretty sight is one of these leafless trees with a big yellow flower on the tip of each branch and twig, with four bright petals and large brown center. After the blossom comes a boll, which opens when ripe like an ordinary cotton boll and brings to light a fine quality of silky fiber, much more lustrous than cotton.

On the plains of the interior occur enormous cactus plants reaching a height of twenty feet or more, the trunk of the *cochinillifer* attaining a diameter of twelve to fifteen inches.

The grape tree, the most magnificent shade tree imaginable, is common in the interior. Its dense foliage covers an area sixty to seventy feet in diameter and its symmetrical surface is usually covered with a bright green vine similar to the mistletoe.

BANANA CULTURE.

Since the banana is one of the most important products of Honduras a description of this country would be incomplete without some description of the culture of this popular fruit.

The banana grows in profusion wherever cultivated below 4,000 feet elevation, but its production for export is confined to the valleys of the north coast, where transportation is practicable. Its cultivation is not attended with the difficulties which surround the growing of agricultural products in this country, for after the first planting it practically takes care of itself, the only labor necessary being the cutting of the fruit and the "cleaning" or clearing of the plantation two or three times a year.

The only large expense connected with banana-raising is the planting of a *finca,* or plantation, though to do this the ground is not even cleared excepting where the "suckers" or roots are planted. No ploughing or leveling is done, but after the suckers have been planted the underbrush is cleared away and the trees felled, and the weather and the ants soon do the rest.

The suckers are set in clusters of six or eight, twelve to fifteen feet apart, and in the course of a few months so many stalks will have developed in each "mat" or cluster that it is necessary to thin them out, eight or ten of the best stalks being left.

Broad leaves unfold on all sides of the stalk as it grows, and at the height of six or eight feet a blossom appears on the end of the stalk, purple in color and six to nine inches in length. Its growing stem soon pushes it beyond the leaves and it hangs down like a large heart. Within this blossom the fruit is developed and soon the outer envelope of the blossom is pushed up, disclosing a double row of buds extending two-thirds of the way around the stem. Each double row or group of fruit is known as a "hand." The next envelope of the blossom soon opens up and another embryo hand makes its appearance an inch or two farther down the stem and on the opposite side; and so the stem continues to grow and the blossom to unfold until its power to produce has become exhausted, leaving a bunch of six to as many as eighteen hands of bananas, beyond which at maturity the curved stem extends two or three feet, with the pointed purple blossom still on the end. A hand contains sixteen bananas on an average.

The bananas are not allowed to ripen on the stalk, else they would lose much of their flavor besides being unfit for shipment. When about three-fourths "full," as the planters say, the bunch of fruit is cut from the stalk. The stalk is also cut down and the root stock sends up new leaves, which in the course of a few months form other large stalks and bear more fruit; thus only one planting is necessary, though the crop is continuous.

Three days each week are occupied in cutting fruit and the remaining work days in shipping it and "cleaning" the plantation.

The fruit is graded as it is loaded on the ships according to the number of "hands" each bunch contains. The transportation company pays sixty to seventy-five cents per bunch and sells the fruit at United States ports for five cents per pound; and, as the average steamer carries about 15,000 bunches of sixty to eighty pounds each it is easy to figure a goodly profit for J. P. Morgan & Co., *alias* the United Fruit Company, by whose grace the few independent planters and independent steamers live and move and have their being.

Though the native complains that the laws are made for foreigners, and no protection to himself, there are many laws which aid him and might be copied with benefit by greater nations.

For instance, each city or town is the undisputed owner of all the land within a radius of three miles of its nominal center, and any native may make his home on any unoccupied portion of this area. So long as he lives upon it and cultivates it it belongs to him; but when he ceases to do so any other native may occupy it upon the same terms. Therefore there is no excuse for a native of this land being homeless or hungry.

Under such favorable conditions it would seem that the country should be densely populated, and one wonders why, when there is a horde of small children about almost every habitation, the villages are so small and the country so sparsely settled. The reason is that the death rate among children is so high as to practically prevent an increase in population.

Almost from birth the children are obliged to take care of themselves, receiving little attention from their elders. Until three or four years of age they go without clothes and are exposed to all kinds of weather and temperature. Hence only the strongest or more fortunate ones survive, the majority dying from contagious diseases or the ills resulting from exposure and neglect.

Amid such prolific surroundings it is not strange that the native is inclined to be somewhat indolent and to dislike prolonged exertion. Poor as he is, he never experiences real "want." Food products are so abundant that the appetite may be satisfied almost anywhere, and it is a matter of great wonder to him that, with all our wealth, people in the United States sometimes suffer actual hunger.

In Honduras everything grows with little or no cultivation, even to the fence posts. If a native wishes to fence his land he does not go through the laborious operation of cutting a tree, splitting it, hauling it and digging post-holes. He *plants* the posts and they grow wherever he desires to have them; for twigs from the *madre de cacao* (mother of chocolate) stuck in the ground, in the course of a year, become large enough to bear poles or wire.

Corn, rice and beans, which form the principal articles of diet, grow without other expenditure of labor than the planting. Chickens and turkeys are numerous and prolific. The native kills his own meat, tans his leather and makes his own shoes, if he wishes any. Seisal grows easily and from it he makes his ropes, bridles, hammocks and other articles. His drinking-cups, water-jars, wash-bowls and all vessels except those used for cooking grow on the trees in the shape of gourds. Cooking utensils he makes of clay.

Practically all he needs to buy are his *machete* and his clothes, and but for a comparatively recent law he would not need the latter. In fact, the material for these is found wild everywhere, for the trees of the forest produce fine cotton and an unappreciated insect spins the strongest and glossiest silk, which, woven into fluttering banners in the tree tops, are a small but conspicuous part of every landscape.

Truly, Nature has been lavish with her gifts to the Honduranian.

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
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THE SUPERFICIAL APPEARANCE AND ALTERATION OF ORE DEPOSITS.

By GEORGE J. BANCROFT.

Read at the Meeting of the Society, April 21, 1911

In order to approach this feature of the study of ore deposits in an intelligent manner, it is desirable to classify the outcrops in a manner entirely different from the classification given in my paper on the 'Genesis of Ore Deposits." In that paper I classified them purely according to genesis. In this case the classification is more than a discussion-room convention, because the first step of an examining engineer is to settle in his own mind the class of deposits with which he is about to deal. Failure to do this simple and logical thing has led to some of the most ridiculous blunders in mining. I recall a case in Sonora that illustrates this point. There is a deposit about ten miles south of Saqui de Batuc called El Cobre Mina, which simply means The Copper Mine. This deposit consists of deposits of copper ore on the lower contact of a porphyry sill, lying in a limestone mountain. The porphyry and the limestone immediately overlying it weathered readily and hence were easily eroded. The underlying limestone was endurated near the contact, the result being that the "contact" formed a bench on the mountain side. The bodies of copper ore lay in bands or shoots trending from the mountain outward. Of course, they have little depth vertically, for they are contact bodies existing only in close proximity to the sill. At the best known part of the bench, called "copper flat," the porphyry and everything above it has been eroded, leaving the shoots of copper ore exposed on the surface. They look like huge crooked veins and were so considered by a group of experienced, but not well informed American mining men from Minas Prietas. They sank two shafts about 200 feet deep on the so considered veins, then drove a tunnel under the flat. Then they dropped the prospect as no good.

The Mexican gambocinos did not know any more about geology than the Americans, but in the course of following the ore they burrowed under the hill along the contact. Then another group of Americans became interested and developed the mine with geological intelligence, opening up a large amount of ore, but the second bunch was, in reality, only a little more intelligent than the first, for the ore, when developed in large quantities, would not pay enough to warrant the expenditure for equipment necessary for production in such an inaccessible place.

The second lesson to be drawn from El Cobre, is, however, a side issue to the purport of this paper, as I will not attempt to go into the complexities of commercial conditions surrounding the development of mines, but shall stick to the geological side.

The first lesson to be drawn from El Cobre is that the examining engineer must first of all decide what class of ore deposit he is examining. As this question is apt to be purely a structural one, I will give a structural classification.

First—Fracture veins.

Second—Contact veins between non-eruptive rocks, i. e., stratified veins.

Third Contact veins or ore bodies between eruptive and non-eruptive rocks.

Fourth—Impregnation deposits on porous strata.

Fifth—Impregnation deposits in crystaline rocks.

Sixth—Pipes and chimneys.

Seventh—Cement deposits.

Eighth—Deep leads.

Ninth—Stock-works.

Tenth—Mineralized dikes or batholiths of eruptive rock.

Eleventh—Segregation deposits in mineralized dikes or batholiths of eruptive rocks.

Twelfth—Cave deposits in quartzite or limestone.

Fourteenth—Fractured strata such as anticlinal and synclinal folds.

Fifteenth—Fractured eruptives, such as explosion vents, etc.

Sixteenth—Lenses in schist or slate.

The brief and incomplete enumeration given above will intimate what a variety of structural forms may be encountered in ore bodies, and I hope my illustration of El Cobre will emphasize the necessity of first determining the form of an ore body.

The engineer who is called upon to examine a prospect need not consider that it is work beneath his notice. Many engineers cover up their deficiencies by turning up their noses at prospects. As a matter of fact, the examination of prospects call for far more skill in all directions than the examination of developed mines. It stands to reason that after the form and structure of a deposit has been exposed by the diligent penetration of the miner and after working costs have been more or less determined by the operator, it is a much easier matter to make a reliable report on a property than when the same property is in the state of a raw prospect.

The engineer is often called upon to decide the future development of a prospect when there is nothing in sight but a ten foot hole with ore in the bottom. I saw the great Combination Mine at Goldfield when it was in this condition. In that particular case the geology was so obscured by the superficial alteration of the eruptives that the true character of the deposit could not be determined, and was not determined until a depth of several hundred feet had been obtained. The only rule applicable was to follow the ore.

It may be said that the rule in any prospect is to follow the ore, but the application of intelligence comes in when the ore plays out. The Minas Prietas men followed the El Cobre ore *down*, but when it played out they did not have the intelligence to prospect the contact under the mountain.

Those two illustrations I think cover the extremes in cases of this kind. In the case of El Cobre anyone with a trained eye could see the structural features of the deposit as plainly as though it were done in a glass model. At Goldfield, on the other hand, a most diligent study of the formation gave no insight into the probable structure of the ore deposit. I will say however, that the Goldfield deposit is the exception and not the rule in the semi-arid regions of the west. Where vegetation is rank, the difficulties of the examiner of prospects are many times increased.

When the immediate surroundings of an outcrop give no indication of its identity, it will very often be found instructive to walk clear around the prospect at a radius of a mile or so. The walls of canons or gulches will often give a clue to the structure. A bold outcrop is often a remnant of an overlying stratum and the local dip of the formation can sometimes be picked up at its base, or the outcrop may be an intrusion or a fault-scarp and in any event it is worth knowing what it is.

Of course, neighboring mines, if any such exist, should be visited and studied as thoroughly as the owners will permit.

One of the most perplexing class of prospects are those which occur in a flat or gently rolling country. As luck will have it, this class embraces many good mines. Where acid waters are prevalent the rocks are softened and the hills take on a soft and rolling contour, while nearby mountains which contain no ore deposits may be very sharp and rugged. In such cases it will often be found useful to climb a neighboring hill and look down at, or over at, as the case may be, the hill of the prospect. At first no structural indications may be apparent, but it pays to make haste slowly in such cases. As the shadows change the structural details may suddenly appear. Sometimes a certain bush or tree will have a fondness for a certain formation and a quiet half hour spent in studying the verdure will often reveal more of the hidden rock structure of a hill than days of digging would do. Thus a vein or porous stratum is apt to be a water way and its outcrop is often marked by water loving shrubs and bushes or by green grass. Slight shading in the soil may also become distinct under changing lights or cloud shadows.

Deep rooted trees are killed or stunted by acid waters, hence a hill barren of trees or containing many stunted trees, in a forested country, is always an object of interest to a mining man. The engineer can sometimes trace out the outlines of a large deposit of sulphide ore by the boundary of the injured timber.

In studying prospects it should be borne in mind that, as a rule, ore bodies do not make coarse pieces of float. I have seen very intelligent men looking in vain for "chunks" of float when the trend of the vein was painted as clear as a stripe on a zebra to the man who studied the finer particles in the soil. A common gold pan is very useful in studying the fines. One can count on the local prospector to have run down any clues of free gold, but the average prospector pays little attention to the black sands. A careful scrutiny of the black sands from a few pans of dirt will often lead to important discoveries.

Having given a rambling discussion of some of the features attending the examination of prospects, I will now take up the different classes as outlined above and try to give a few pointers that will help to distinguish them.

First.—*Fracture Veins*: I use the word fracture in place of the word "fissure," because our highly respected courts have defined and redefined a fissure vein till the definition resembles a free trade bill that has been thoroughly amended by a Republican Congress.

A fracture vein is primarily formed by a dislocation of the country rock. As a rule the vein is a fault fissure; that is, one wall has moved with respect to the other wall. For this reason fracture veins are more or less like plane surfaces.

The force which caused the faulting having had a definite direction, the lines of yielding also had a definite direction, and hence fracture veins are roughly tabular, in most cases.

It is difficult to conceive of a thing so hard and brittle as a rock, yielding in one place and not yielding in another place a few hundred yards away. I think it is an unreasoning feeling of this kind which prompts the prospector, who has discovered a vein, to trace the same, in his imagination, through several counties. I have frequently heard old mining men start with the Little Johnny vein at Leadville and trace its course through Lake County, Summit County, Clear Creek County and Gilpin County, winding up at some mine in Boulder County. Of course, each one followed a different path because each one wanted it to wind up at his particular prospect, but they all showed the instinctive idea that a fracture in our enduring granites must persist indefinitely. Unfortunately this is not true. A vein which marks a throw of several feet at one point may fade out entirely only a short half mile away.

This point is important in considering prospects. The engineer is often shown two ten foot holes which disclose strong veins. The holes are a mile or so apart and the veins trend in the same direction. He is thereupon assured by the prospector that these two holes are on one and the same vein and that there is continuous ore from one hole to the other. If the engineers dares look a wee mite sceptical, the prospector proceeds to absolutely prove his assertion by the use of a divining rod.

However, if a vein gives evidence of a large throw and the country rock is hard, it is safe to assume that the vein will persist in strike and depth for considerable distances, say a few thousand feet. If the country rock is soft and pliable, as, for example, clay shales, and the throw is small, it is not safe to assume much permanence to the vein in any direction. The vein's throw is shown by slickensides, gouge-streaks, etc. Occasionally one may find in an interrupted feature of the country rock on both walls of the vein which will accurately show the distance and direction of the throw. Such information is very useful when it can be obtained, but in prospects one can seldom get it.

As previously mentioned, fracture veins are roughly tabular in form, but it must be borne in mind that they are only very roughly so. In areas like the San Juan Range, Colorado, where the white quartz veins stand out very strongly and can often be seen extending for hundreds of yards, it will be noticed that they are far from planes. The outcrops are often as crooked as a twig. However, in examining an undeveloped prospect, it is often necessary to follow out the extention of the vein, and the only clue to its direction that we have is on the assumption that the vein is tabular. Having ascertained the dip of the vein, we may then imagine how a plane surface having that dip would cut the contour of the particular locality. In a rough country it is surprising how crooked will be the outcrop of an inclined vein. Many a prospector has lost valuable property by failing to realize the rudiments of conic sections. If a vein dips into the hill and the outcrop crosses a gulch, the outcrop will extend up that gulch in a V shape. The angularity depending, of course, on the degree of dip, the steepness of the hill and the depth of the gulch. Similarly if the vein dip with the hill, the outcrop will extend down the gulch in a V shape. These two illustrations are simple, but where we have crooked and slanting gulches, crooked veins and varying slopes, it is often very difficult to trace out the outcrop of a vein. A simple plan is to take a book or piece of board and holding it parallel in dip and strike with the vein, sight across it to the hill or gulch where the continuation is sought.

Fractures may occur on one of the bedding planes of a sedimentary series as the Durant mine at Aspen, Colo. Such veins must not be confused with our next class (stratified veins). The difference lies in the fact that in the case of the fracture veins there has been movement and distinct fracture along the bedding plane while the stratified vein results from percolation along the unfractured bedding plane.

Second—*Contact veins in non-eruptive rocks, i. e., stratified veins.* This class is generally very easy to identify. The fact of the un-faulted stratification paralleling the vein as a rule settles the matter. There are, however, bodies of eruptive rock which have been given an apparent stratification by movement and pressure and fracture veins in such rocks are often parallel to this schistosity or apparent stratification. This is particularly true of diorite areas. Then again, fracture veins sometimes result from very little movement and make a very small angle with the stratification and may run absolutely parallel with it for some distance, so the engineer must not jump to conclusions.

Stratified veins are not, as a class, highly thought of. It seems to be a rule that they are pockety and unreliable. The flats of the Black Hills are a notable exception to this rule. It sometimes happens, however, that a stratified vein may cross from one stratum to another and the system as a whole may make a very valuable mine. This condition is very apt to be overlooked by the miner. He digs out the pocket that outcrops and abandons the mine, or worse, yet, blows in all his profits and more too, prospecting the stratum of the original ore body, whereas, had he closely observed the foot and hanging walls he might have observed a little stringer that would have led him to another ore body. The Golden Cloud mine in York Gulch, Montana, is a stratified deposit of this character. It consists of a series of flat stratified pockets connected by small quartz verticles.

Third—*Contact bodies between eruptive and non-eruptive rocks.*

This class is very easy to distinguish and a very reliable class to prospect. It is true that the eruptive sometimes extends out into the surrounding rocks in tongues of irregular shape, making it difficult to follow the contact, but as a rule such conditions are very local. If a prospect shows good ore at one point on a contact and not elsewhere, a very close study of the local conditions should be made. It not infrequently happens that all the ore will make on the contact between the eruptive and a certain stratum or variety of the surrounding rocks. Thus, at Bisbee, Arizona, there is a mineralized contact between granite porphyry and bedded limestones, and all the ore is confined to that part of the contact where the porphyry and a certain bed of soft yellow limestone (carboniferous), come together. As this particular horizon outcropped at only one point the early development of the camp was slow and marked by much exploration work which in the light of present knowledge looks very foolish.

Fourth—*Impregnation deposits in porous strata.*

This class is closely allied to stratified veins. The only real difference is that impregnation deposits generally extend out from some well marked contact or fracture vein while stratified veins are not so readily connected with any general system of mineralization. Impregnation deposits are usually the richer the closer to the channel of supply, and the leaner the farther away from it.

A granular or porous stratum is always more likely to be enriched than a dense one.

*At Clifton, Arizona, the granular paleozoic limestone beds are, in some instances, mineralized a distance of 2,000 feet from the nearest porphyry. It is probable, however, that more or less open veins aided in conveying the mineralized solutions so far away from the eruptives.

Fifth—*Impregnation deposits in crystaline rocks.* Such deposits are often hard to recognize in the prospect stage. Cripple Creek is a camp whose ore bodies are largely of this class, and we know it was scratched over quite a bit before its value was recognized.

The impregnation deposit, as a prospect, generally looks like a narrow vein with a reddish or brown discoloration of the rocks on both sides of the vein. As most all veins are accompanied by bands of discolored rock, I know of no way to be sure except to assay the discolored country rock alongside an ore body. For some reason the values of veins are generally confined strictly within the walls, but nevertheless it is the duty of the examining engineer to keep his eyes open for impregnation deposits.

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*Waldemar Lindgren, P. 546, Vol. 35, Trans. Am Inst.

Just the other day I saw a pretty example of crystaline limestone impregnated with pure resin zinc. The operators were throwing this ore over the dump when an experienced mine manager came along and told them that they better put that stuff containing the yellow crystals in the ore house.

Sixth—*Pipes or Chimneys*: It usually requires but little work to prove that a deposit is not a vein or contact, and then, of course, the only thing that will save it from the pocket class is that it be a pipe or chimney. Unfortunately true pipes or chimneys are rare, while isolated pockets are many. There is no certain way to prove whether a prospect is a pocket or a pipe except to sink on it, but sometimes one can find scinter or onyx, or other evidence of geyser action, and it is supposed that most pipes are the channels of extinct geysers. Where such evidences are found it is a fairly safe proposition to sink, in case the values are attractive.

Seventh—*Cement Deposits.* This class is easy enough to recognize, and presents no difficulties of examination or prospecting. They are superficial deposits and readily explored with churn drills or shallow shafts. They are formed in two ways. First—In desert regions the underlying gravels are generally cemented by calcite and alkalies. In case these gravels are rich enough in gold to work we have a cement deposit. Such are the cement deposits of western Sonora and Western Australia. Second—The solutions issuing from a vein may make a mineralized cement in the soil. This may occur with primary or secondary solutions, but as a rule the solutions are secondary, and hence gold is rarely found in such cement deposits because gold does not readily yield to secondary leaching. In the first class the deposit is prospected just like a placer channel and in the second class the deposits are generally soon traced to some strong vein which marks the origin and upper end. There are some cement copper deposits east of Hawthorne, Nevada.

Eighth—*Deep Leads.* This class is easily recognized because the ore is very evidently river gravel which has been buried under eruptive flows. Once the trend of the old river channel is determined they are readily followed. California and Victoria, Australia, are noted for their Deep Leads.

Ninth—*Stock-Works.* Stock-Works consist of a multitude of little veinlets crossing each other in all directions. In-as-much as the values are usually confined to the veinlets or some of them, and as the individual veinlets are too small to work, a stockwork suggests to the mind a large body of low grade ore. It is usually low grade, and unless it is large it is not interesting. Stock-works may be of any size and shape. Unless one can get some inkling of the forces that produced the fissuring it is impossible to form any idea as to the probable trend or dimensions of a stock-work. At Berners Bay, Alaska, are several notable stock-works of which the Kensington mine is the best known. The stock-work here occurs in diorite and probably is caused by local straining which left a fractured zone in place of a clean fissure.

Tenth—*Mineralized Dikes or Batholiths of Eruptive Rock.* It is not as a rule difficult to recognize this class because the ore is evidently a different rock from the surrounding country. Occasionally, however, one finds a mineralized dike in a country of similar eruptive rock. In such a case a good microscope comes in handy. One can generally find some distinguishing feature of the mineralized dike and so trace out the float.

Eleventh—*Segregation deposits in eruptive dikes, or Batholiths.* In the prospecting stages the boundaries of this class of deposit are very hard to determine, because they are so entirely irregular in outline. The limits of the ore body are not fixed by any wall or cleavage, neither is there any connection between one ore body and another. Unless the ore bodies adhere to a contact it is simply a case of going it blind.

The evidences that an ore body is one of magmatic segregation consist of the negative observations that it is not on a vein or contact, that it is not an anticlinal fold nor a stockwork and the positive observations that the ore is eruptive rock in which the metallic crystals are *intergrown* with the rock forming crystals.

Twelfth—*Veins in Bedded Eruptives.* This class is unusual in that the veins may be confined to one bed, and hence they are a dangerous class. As an example I will mention the southern group of the Batuc Mines of Sonora. These mines consist of several very strong and rich quartz veins which occur on the east slope of Batuc Mountain. This mountain consists of bedded eruptives. The east slope conforms to the bedding. The west slope exposes the truncated edges of the beds. At the time of my visit the wily Mexicans had cleverly covered up all the deeper works which had penetrated the underlying beds because the veins are entirely confined to one bed. This bed is of adesitic rock about 500 feet thick at its thickest place. The veins do not penetrate either the underlying beds or the overlying beds. The underlying beds were examined with the aid of a rope on the western face of the mountain, which is a sheer precipice. The eastern slope dips gradually down to a gulch, the far bank of which consists of overying beds of rhyolitic rock. The veins do not penetrate this rock, but do apparently go down undiminished in strength and richness on the dip underneath the overlying beds.

This illustration brings out both the dangers and the possibilities of veins in bedded eruptives. While the veins very likely will terminate at the lower limit of the bed, they may just as likely extend indefinitely in the lay of the bed.

Thirteenth—*Cave Deposits in Quartzite or Limestone.* For some reason not fully understood by me, cave deposits are practically confined to calcareous rocks. Quartzites are often calcareous, and when such is the case they often harbor caves. Limestones are notorious for their caves. An ore deposit occupying a cave is easily classified because the ore is geenrally a soft "filled-in" substance and there is generally an open place along the top of the cave. Sometimes as at the American Nettie Mine, Ouray, Colorado, the cave is mostly empty with a deposit of enriched gravel in the bottom. The outcrop of such deposits looks like an ordinary deposit in limestone, but a very little development reveals the cave character. Cave deposits are generally in groups, and diligent search will usually reveal an open channel leading from one deposit to another.

Fourteenth—*Fractured strata such as anticlinal and synclinal folds.* This class often laps over upon stock-works on the one hand and upon impregnation deposits on the other hand. Still there is a distinct class which is not covered by the other divisions. At Bendigo, Australia, the sedimentary beds are crimped into sharp folds with pretty regularity, the brittle strata, consiststing of shaly sandstones, were crumbled on the anticlines and eventually entirely decomposed by the solutions which found these fractured zones a favorable circulation conduit. On the anticlines and some of the synclines they have been entirely replaced with gold bearing quartz. Thus we have the beautiful "saddle reefs" of Bendigo. I walked nearly a mile through an old stope and it reminded one of walking on top of a hugh elongated boiler with an arched roof overhead.

It is seldom that anticlinal folds take the simple and beautiful form of the saddle reefs at Bendigo, but varieties of this form of deposit are more common than is often suspected. In eruptive areas the beds are apt to be folded and twisted. The more brittle beds are likely to be crushed, thereby forming a favorable channel for mineralized solutions. Such areas may not be recognizable as anticlinal or synclinal folds, yet they are crushed zones due to flexure. In practice they are apt to be called big pockets or deposits and let gone at that.

To the examining engineer, however, it is not sufficient to class an ore body as a big pocket if it is possible to decipher its structure, because if the structure is understood, developments may be intelligently carried out to find the extension of that body or another similar one.

Fifteenth—*Fractured Eruptives, Such as Explosive Vents, etc.* The "crater" at Cripple Creek is a good example of this class of deposit. This enormous shoot was apparently an explosion vent which filled up with loose detritus. It naturally formed a favorable passage for mineralized solutions, but if one may judge from results there was too much channel and too little solution, for the material is very low grade. Deposits of this character are simply loose masses of broken country rock more or less cemented together with quartz and mineral. Such deposits are very continuous in depth if the body is a true explosive vent.

Sixteenth—*Lenses in Schist and Slate*: This class is a very important one. Such famous districts as the Angels Camp district of the Mother Lode, California, the Homestake, in the Black Hills, Dakota, and Silver Peak, Nevada, come under this class. Sometimes the lenticles are connected by veinlets, sometimes not. Where there is no connection between any of the lenticles, it is thought by some that there has been movement in the slate or schist since the lenticles were formed, thereby obscuring the original connecting links. In early prospecting stages this formation can generally be deciphered by surface indications. If the lenticles are sufficiently close together on the surface to warrant fairly easy development, the same may be assumed as a probable condition at depth. If, on the other hand, the lenticles are so scattered on the surface that all the profit from one would be lost in finding another (in case the same condition prevailed underground), it is pretty safe to pass the proposition along.

Superficial Alterations.

Having briefly skimmed over some of the structural problems which must be worked out by the engineer, I pass now to a few words about the character of the outcrop itself.

If the prospect gives no evidence of any value but gold, it is generally a safe assumption that the superficial zone is somewhat richer than the unoxidized vein below. The reason for this is that gold is so chemically inert that it rarely yields to surface leaching. Hence we have all the gold left in the vein and part of the iron, sulphur and other minerals gone. The result is that while the leached zone may not be any richer per cubic yard, it is richer per ton.

It must be borne in mind, however, that no rules are absolute. Gold sometimes does leach away from the oxidized zone and leave a barren outcrop over a rich ore shoot. The Kendall Mine in Montana is an example of this.

Where the iron of a vein has been oxidized to hemitite no leaching of the gold may be looked for, but where the iron has formed limonite and been largely washed away it will often carry very fine gold in suspension. I proved this by experiment in the McBreen Mine, Siskyou County, California. Where gold occurs in the vein as a salt, such as a telluride, selenide, or sulph-arsenide it is more apt to leach away than where it occurs as metallic gold.

Silver goes into solution readily, but owing to its great affinity for chlorine it seldom migrates very far, the silver chloride being a very insoluble salt. Hence silver outcrops are often barren, but good ore is often found 30 or 40 feet from the surface.

Copper, on the other hand, is not only readily taken into solution by oxidizing waters, but it is not readily precipitated. Hence copper outcrops are often barren to depths as great as 600 feet.

The study of leached outcrops is one of the fascinating features about examining prospects. A careful study of the outcrop will sometimes result in finding pseudomorphic cavities which may give an idea of what the ore was before leaching.

The rules of surface alteration vary with the climate. In desert regions there is generally an important zone of secondary enrichment. In moist localities which have been heavily scored by glaciers, like the coast of British Columbia, the zone of secondary enrichment is almost wholly lacking and oxidation rarely extends more than 50 feet deep. The age of deposits is another disturbing feature. There is evidence in some deposits that alterations took place under conditions totally different from those existing today. Thus the copper outcrops on the lower Bill Williams Fork in Arizona look very different from similar outcrops in similar formations, but at a higher altitude. There are a few residues of recent beach gravel in the lower country and I think the inference is justified that the leaching of the lower outcrops was assisted by the action of tide waters. The lower outcrops are more honey combed and show less carbonate of copper than those above the beach-gravels.

In the above discussion I have omitted all mention of faults and foldings which may occur after the ore body's formation and so distort the same. This a subject in itself and may well form the subject of a separate paper.

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THE 105TH MERIDIAN IN DENVER
AND ITS MILE HIGH LEVEL.

By HERBERT A. HOWE.

Read at the Meeting of the Society, June 3, 1911

From the Report of the Chief of Engineers for 1873 we learn that Prof. T. H. Safford built a pier in Denver and tied it geodetically to the flagstaff of the old U. S. Mint. In the U. S. Coast Survey Report for 1874 we have further information, and in the Report of the Chief Signal Officer for 1880 there is a description of the location of the pier, which was used in determining the position of the instrument employed by Mr. Wm. Ainsworth of this city in observing the total solar eclipse of July 29, 1878.

For our present purposes the matter is summed up in the following extract from a letter from Superintendent Tittmann of the U. S. Coast Survey, under date of April 13, 1909:

"The latitude and longitude of a station in Denver were determined in 1873 by the Coast and Geodetic Survey. This station was located about 166 ft. north of the Denver & Rio Grande R. R. depot, and was marked by a brick pier two feet square, two and a half feet above the ground, and about two feet below the ground. It was built by Prof. T. H. Safford in 1871. This pier was 651·16 meters or 21·12″ north of, and 240·27 meters or 10·09″ west of the public school house central spire. The astronomical latitude of this pier is 39° 45′ 21·71″ and its astronomical longitude is 104° 59′ 34·35″, which places the 105th meridian (astronomical) 25·65″ or 610·6 meters west of the pier. We have no information as to whether this pier is still in existence. There is no recent determination of any other point in the city."

The public school house referred to in the above letter is the old Arapahoe street school. The Club building is now in front of the old school, and the superstructure of its cupola has been removed, only its base remaining. The Coast Survey pier has long since disappeared. It was erected north of the intersection of Nineteenth and Wynkoop in the railroad yards. Two years ago a traverse was run from the Arapahoe street school to the location of the government pier, using the data given in Superintendent Tittmann's letter. Diligent digging on the site of the pier failed to reveal any trace of its foundation. An old employe of the Union Pacific, who remembers seeing the broken capstone of the pier lying on the ground near its location, has told the writer that the level of the surface in that vicinity has not been altered particularly since the days when the pier was there. Mr. Wm. Ainsworth has also testified to the same fact. He has further said that in 1878 Mr. O. H. Tittmann and himself found a portion of the foundation of the monument, the part above ground having disappeared.

In Superintendent Tittmann's letter are given the astronomical coordinates of the pier; it is to be noted that they differ from the geodetic coordinates.

Prof. Mansfield Merriman states on page 183 of his Elements of Precise Surveying and Geodesy that:

"It is well to note again that the latitudes and longitudes used in geodetic work do not generally agree with the latitudes and longitudes obtained by astronomical observations. Thus, if the coordinates be found astronomically for an initial station P, together with the azimuth of P′, and if the distance PP′ be directly measured or be found by computation from a measured base, then the latitude and longitude of P′ and the azimuth of P′ can be computed by the methods of the last article, and these computed values are called geodetic ones."

In the present case the initial stations are in the eastern part of our country, on the Atlantic coast, and the chain of triangles has been carried past us across the continent, other stations being picked up in the progress of the work. So great are the distances involved, and such are the station errors that the geodetic longitude of Denver differs about 13 seconds of arc from the astronomical longitude. For the dome of the Chamberlin observatory we have the following figures:

Astronomical longitude, 104° 56′ 56·11″.

Geodetic longitude, 104° 57′ 8·79′.

Here is a difference of 12·68 seconds of arc, which, at our latitude and elevation above the standard spheroid, amounts to nearly 992 ft., one second of arc in longitude equaling 78·212 feet. The 105th geodetic meridian in Denver is thus nearly 1,000 feet east of the astronomical meridian. At Colorado Springs the difference between the two longitudes is 25″, because of the attraction of Pike's Peak and the mountains back of it, which displaces a suspended plumb bob. At San Francisco the difference between the two values of the geodetic longitude obtained by using respectively Clarke's 1866 spheroid, and Bessel's is 12″.

We may gain information as to the relative stability of the astronomical and geodetic meridians by a letter from Superintendent Tittmann, under date of May 23, 1911:

"In reply to your letter of May 18, 1911, I have to inform you that the data of the latitude and longitude of Denver, given in my letter to you of April 13, 1909, have not been changed. It is probable that the future longitude work in the United States will not disturb the old adjustment of the net, the links simply being forced in between the old points. We have no geographic positions in Denver at present. A party is now at work on the reconnoissance for an arc of primary triangulation extending from the vicinity of Colorado Springs to the Canadian border, approximately along the 105th meridian. All prominent objects, such as towers, cupolas, church spires, etc., in Denver will be determined by this triangulation. It is expected that the observing for it will be done next summer—1912. The positions of such objects will be sent you as soon as they are available."

We shall confine ourselves in this paper to a consideration of the astronomical 105th meridian.

Three surveying classes of the University of Denver have worked at the problem of the position of the 105th meridian, the class of 1910-11 doing most of the work, and finishing the matter. The first step was taken about fifteen years ago, when the students measured a base line at University Park and triangulated in to two points in the city, the old smokestack of the Pioneer building at Fifteenth and Larimer, and the flagstaff of what is now called the Continental building at Sixteenth and Lawrence. They also measured short subsidiary bases on the roofs of the Railroad building and the Daniels & Fisher store, and thus connected the two points just mentioned with the flagstaff of the U. S. Mint and the cupola of the Arapahoe street school. These two almost wholly independent systems of measures connected the Chamberlin observatory with the government monument. The position of the observatory was thus doubly obtained, the two results agreeing very well. Since the triangles were very ill-conditioned because of their wide departure from equilateralism, special care was devoted to the measurement of their angles, the principal ones being determined by several independent repetitions with an excellent Saegmuller engineer's transit. The probable errors of these angles were only about 1·5 seconds of arc. The orientation of the University Park base was effected by Pole star observations, and that of the short bases in town by sun observations. Afterwards the U. S. Geological Survey conducted a triangulation of the city. They made the difference of longitude between the school and the observatory exactly the same (to the tenth of a second of arc) as the class made it.

Two years ago a class measured a short base on the Eighteenth street curb near the Arapahoe street school, and triangulated on its cupola base; from this base a traverse was then run down Eighteenth to Wynkoop, and on Wynkoop to Nineteenth, and on Nineteenth street for a distance of 59·28 feet to a cross cut in the stone. This cross had been made by the city, and was directly west of a near-by section corner toward which one of its arms points. The bearing of the Nineteenth street curb was determined by Pole star observations.

This year the class ran from the cross just mentioned along the 19th Street curb to the Platte River, and located there on the bridge a point lying on the 105th meridian, marking it by heavy nails in the wood work of the bridge. It was found that the 105th meridian ran close to the east side of Navajo street, on the north side of the river, and also ran considerably west of the Union Depot.

Since a city map showed that the meridian thus located ran near or through Lincoln Park, the class next ran a traverse from the above mentioned curbstone cross on 19th to Wynkoop, down Wynkoop to Cherry Creek, across the creek to 13th Street, down 13th to Walnut, down Walnut to 8th, up 8th to the east curb of Navajo, and southward on this curb to Lincoln Park, and thence through the Park. All angles and their explements were measured by six-fold repetitions. The last line of the traverse was oriented in Lincoln Park by pole-star observations taken in such a way as to favor rapidity and accuracy. Nearly 650 feet north of the transit in the vertical plane of the pole star at the time of observation a leveling rod was supported horizontally, lying nearly east and west. The instrument was then set with two opposing leveling screws in the vertical of the star, and was carefully leveled in the direction at right angles to this by the use of the level under the telescope. The horizontal limb was set at zero, the vertical limb at the approximate altitude of the star, and the latter was found at or just before sunset, by using the lower clamp and tangent, and bisected while the time was noted to the nearest second by a chronometer. The telescope was then directed to the rod and a reading taken on its target. Loosening the upper motion the telescope was reversed, the horizontal circle reset at zero, and the vertical circle at the proper altitude so that the star, still invisible to the naked eye, was quickly bisected, the time being again noted and another rod-reading taken. These two observations made a set in which the instrumental errors were largely eliminated. To insure independence in the sets the instrument was releveled by the east and west screws as before, and another observer made a set. It was thus possible to take several sets in the twilight before the wires and level target became invisible. In the present case two instruments and two rods were used, and the observations finished by lantern light a few minutes after darkness had set in. The distances of the instruments and the level rods from the last line of the traverse were known, and the determination of the azimuth of this line became then a simple matter of trigonometric computation. Hence the azimuths of all the lines of the traverse became known.

Since the longitude of the point at the beginning of the traverse was known, it was then possible to compute the longitude of the point at the other end of the traverse. It was found to be within a few feet of the 105th meridian, which therefore nearly bisects Lincoln Park. The meridian prolonged southward strikes through the old Overland Cotton Mills, and a mile further south crosses the Platte about 6,000 feet east of St. Mary's Academy on Loretto Heights. By a traverse run from the Chamberlin observatory westward chiefly on Evans avenue, it was found that the chimney of the cotton mills is about 100 feet west of the 105th meridian. The meridian extended far to the south passes through the western foot of the highest elevation on the foothills near Pike's Peak. This elevation, as seen from University Park, appears to lie against the foot of the left hand slope of the peak. As seen from the center of the city it is the first projection at the left of the peak.

A heavy nail has been set a short distance underground near the south edge of Lincoln Park, and another near the northern boundary. From these the position of the meridian there could be easily marked by permanent monuments.

As a more conspicuous place would be on the 16th street viaduct, a line has been run along that causeway from Wynkoop to a point beyond the old castle in River Front Park, which is now the headquarters of a lumber firm. Near this building this line is connected with another which runs across a dumping ground to the Platte and over it to a conspicuous steel stack. This last line is nearly in the vertical of the pole star at its western elongation, and was used in orienting the course on the viaduct. The 105th meridian intersects the viaduct about 1,300 feet from Wynkoop street.

Perhaps the best illustration of the accuracy with which the young men have done their work is afforded by their determination of the direction of the line in River Front Park. On April 20, 1911, they worked there for fifty-five minutes, observing the pole star. The probable error of the mean of their results was less than a second of arc. The instrument used was a surveyor's transit manufactured by Ainsworth of Denver.

Considering the relative sizes of the instruments employed, this work compares favorably with similar work done in Colorado by the Coast Survey in the course of the Transcontinental Triangulation.

THE MILE HIGH SIGN ON THE STEPS OF THE CAPITOL.

When the N. E. A. was about to meet in Denver in 1909, Professors Cannon and Bethel, of the East Side High school, were prominent in arranging for the entertainment of the visiting school teachers. On sundry occasions they had spoken to the writer about the desirability of having some mile-high point located in a prominent place in the city, to do away with the prevalent confusion. Therefore, in the spring of 1909 a surveying class of the University of Denver investigated the mile high mark at the corner of Colfax and Broadway, and also the similar mark on the El Jebel Temple. The former was found to be 15·88 feet too low, and the latter 3·44 feet too high. Therefore neither of these was correct, and the young men ran a line of levels from the bench mark on the east front of the Capitol around to the steps on the west front. From these measures, which will described more in detail later, it was found that the top of the second step above the landing on the main steps at the west front of the Capitol was a mile above sea level.

On June 30, 1909, Professor Ellsworth Bethel, Professor Geo. L. Cannon, and the writer met by appointment at the west front of the Capitol, and the latter pointed out the mile-high step, and mentioned his former suggestion that the riser of this step be marked by a suitable inscription. The party then went to the east front, and talked about a project which originated (it is believed) with Professor Bethel to set up a suitably marked cube on one of the lower pedestals of the east entrance. It was finally decided to hold the matter of the cube in abeyance. Professor Bethel called out Mr. Wm. K. Burchinell, Secretary of the Board of Capitol Managers, and explained the matter to him. As a result of the interview Governor Shafroth was consulted by Mr. Burchinell, and proper authorization was given for placing the brass sign on the proper step.

The intention was that the sign be replaced in time by an inscription chiseled in the stone. Professor Cannon suggested the cutting of a large arrow in the stone platform to mark a north and south line, and Professor Bethel expressed the opinion that the U. S. Geological Survey might be willing to verify the work and put one of their regular bench marks on top of the stone step. Neither of these projects has been carried out.

At this interview it was also suggested that as the University of Denver possessed a hundred-foot tape which had been standardized at Washington, and other necessary subsidiary apparatus, a standard of length could be put in the basement of the Capitol; a suitable place for its establishment was found.

Returning to the subject specially in hand, we proceed to tell of the data used and the operations carried on, in establishing the mile-high level on the steps of the Capitol.

There are on the Capitol grounds three bench marks, one of which is on the top of the southern one of the two granite pedestals at the foot of the steps at the east front of the Capitol. It is marked U. S. B. M. The elevations of these three bench marks have been accurately determined by the U. S. Coast Survey. The latest adjustment of the level net is by Hayford and Pike, and was published in 1909. From page 86 of that publication we learn that the elevation of the bench mark in question is 1,609·0192 meters above the sea. It is interesting to note that the height given in the Coast Survey Report for 1903 is 1,609·1534, while that given in the Report for 1899 is 1,609·0151. The 1899 and 1909 values therefore agree very closely, and the 1903 value is about five inches greater. We remark, in passing, that when the transcontinental leveling reached Seattle in 1904 "the discrepancy between the elevations based on sea-level from tide observations at that point, and the elevation of Cheyenne as adjusted in 1903 was 18·5 millimeters." This equals 7·5 inches, and is a gratifying indication of the accuracy of the work from ocean to ocean. When measures are at present made so accurately, it is plain that we may not expect that any future work will greatly change the values now assigned for the elevations of the Denver bench marks. The 1909 value of the elevation of the bench mark on the granite pedestal at the east front of the Capitol, when reduced to feet, is 5,278·9238 feet.

The young men of the University had therefore the simple job of starting at this bench mark, and running a line of levels around the south end of the Capitol to the west steps. Short sights were taken, the distance from an instrument to the rod never exceeding 60 feet. In some cases it was less than 25 feet. Four instruments were used; two were Ainsworth transits with 20-second level bubbles. The others were wye-levels, one loaned by the State Engineer, the other a beautiful new instrument furnished for the occasion by the Ainsworths. The difference of level between each pair of adjacent stations was determined seven times, on the average.

This work was checked on another day by the writer and his son, Warren F. Howe, to make sure that there was no chance of any gross error. The check differed from the former value 0·′003. The step on which the sign has been placed slopes about one-half inch from back to front, and the mile-high level is near its back edge.

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THE UTILIZATION OF THE ZINC CARBONATES AND SILICATES OF LEADVILLE, COLORADO.

By F. L. Clerc.

To be Read at the Meeting of Section 1, of the Society, Sept. 9th, 1911.

The recent discovery of Carbonate of Zinc ores at Leadville, in considerable quantities, if we can trust newspaper reports, of ore in sight, or of the area over which it extends, and its range in depth as exposed in the different levels of the old workings, cannot fail to interest many members of this society.

Problems which will appeal to many will present themselves for solution, and I do not doubt that some of our members will be called upon to contribute to the successful solving of them.

These problems, I believe, will present themselves at all points throughout the very extensive field of metalliferous mining and metallurgy, the tracing of the geological relation of these new ores to the deposits already worked out and their relations to property lines and consequently their ownership, the taking out of old mine timbers and retimbering. In short, the selection of the most economical plan for mining these ores, with all which this involves, in connection with the old workings, are sufficient illustrations of problems on the mining side of the subject. On the side of metallurgy, the ores are new, and new ores always present problems.

By problems I do not mean difficulties. When we know how to do anything, however difficult, it is no longer a problem; we can estimate its cost in time, labor, or money, and decide whether it is worth doing.

The problems likely to arise in connection with these new ores may be grouped in two divisions: How to get them out of the ground and what to do with them when they are on the surface. Problems in the first division may not arise and need not be anticipated. Difficulties there will be, but overcoming difficulties makes up the life work of the mining profession.

Problems in the second division may be considered from two standpoints, the ore producers' standpoint and the smelters' standpoint. To make this distinction clear, these may be formulated: How to bring these ores up to the standard grade required by present market conditions, and, on the other hand, how to make use of these ores by a modification of present furnace practice. The problem is the same from whichever side it is approached, for it is the utilization of the ores. The solution of the problem depends mainly on how far it is possible to go from either side; on how much the miner can do to raise the grade of his ore, and how much the smelter can do to improve his practice. Keeping in mind the difference between a problem and a difficulty, although a hard and fast line of demarcation cannot always be drawn, we can leave the difficulties to the managers of the mines and smelting companies. In the acknowledged problems our assistance is sure to be called for, and I do not doubt that many of our members are prepared by the actual knowledge and experience to work out a solution and demonstrate it.

Eliminating, therefore, as much as possible, those ores which can be marketed under present conditions, that is, all which can be sold profitably as they come out of the ground, and those which by concentration, by any of the known and practiced methods of concentrating, using water, air, oil, electricity and magnetism, singly or combined, can be profitably brought up to the required standard, as giving rise to no problems, our problems are connected with those ores which will not bear mining, transportation and treatment charges. How important the amount of these may prove to be, I cannot say from personal knowledge. I have only seen hand samples. We all know how little we can judge from a hand sample. If it is an average sample it may be as good to form a judgment upon as a lot of a million tons; on the other hand, it may be only an interesting cabinet specimen.

From my own standpoint, the hand specimens I have seen present a serious problem. I do not think such ores can be marketed profitably on an extensive scale under present industrial conditions. It is quite possible that to others this is only a difficulty to be overcome. In either case I trust that the opinions I am about to express will lead to the opening and general discussion of the broad subject, "The Recent Discoveries of Carbonate of Zinc at Leadville;" how much is there of it, what is it like, and what can be done with it?

Subject, then, to correction by better informed specialists, I express the opinion that the great body of these ores cannot be improved to an extent which meets present market conditions by any known method of water, air, oil, magnetic or electric concentration. At the same time, it is at once evident that much of the zinc which is in them can be driven off by putting them into a fire; that is, by mixing them with fuel and blowing air through the mixture.

As is very well known most of this sublimed zinc oxide can be caught in flues, chambers and muslin or woolen bags. Here is a ready method of concentration. As to the degree of concentration, it may be assumed from published results of past experience, that from carbonate and silicate zinc ores, containing not more than 10% to 15% of zinc, we can obtain a sublimed product, assaying 70% to 75% of zinc. Questions of costs and savings can be set aside as difficulties and left to the parties most interested, as they must be, for they can only be estimated from a full knowledge of local conditions.

It is possible, however, to take a broad view, and, regarding this sublimed product as concentrated raw material, ask what can be done with it. Except under very exceptional conditions, with selected ores and specially favorable fuels, it must be admitted that it will not possess color or texture required of a pigment, but admitting that it had both, the outlet in the paint market would not be large enough to admit more than a few thousand tons per annum. As a raw material for spelter making, it can be said that it ought to be able to stand transportation charges better than 60% or even 66% ores, and at the present time, or in recent years such ores have been carried to distant smelters even across the ocean. This question then resolves itself into a difficulty to be left for local consideration and answer.

I will now approach our hypothetical problem from the opposite side—the smelters' side—and ask your attention to the question, how far is it practicable to modify present furnace practices so as to render these new ores more available.

You will bear in mind that we are now considering only those ores over which the miner and smelter cannot meet each other on the question of price. The problem involves a modification, and, before a modification can be even suggested, it is necessary that some idea must be had in mind of the thing to be changed, and of the exact alteration to be made in it.

To secure this mental attitude of attention and establish common premises, I shall outline the thing to be modified. This outline will lack in perspective, will be deficient in detail, and it may by some be judged to be lacking in accuracy, but it may be assumed as a starting point, a working hypothesis.

Here, then, on the blackboard is a picture of a zinc retort and its condenser. This is the single cell, the unit structure, out of which the whole spelter industry is elaborated by the simple process of reduplication. Thirty years ago I built a furnace to hold and heat four hundred (400) of these retorts. I had previously seen in operation a furnace containing eight hundred and sixty-four (864) retorts, and ten years ago, I can say from my own observation, six hundred (600) retorts to a furnace was the usual number. The working of the furnace is

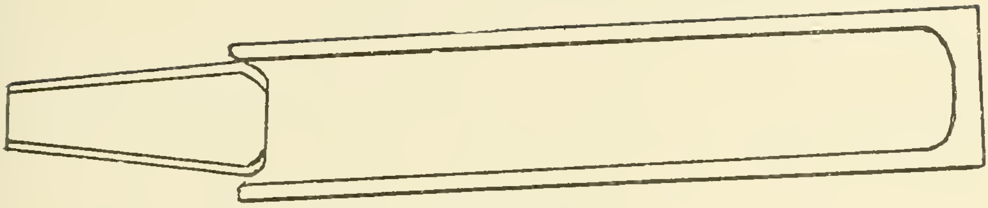

fig 1

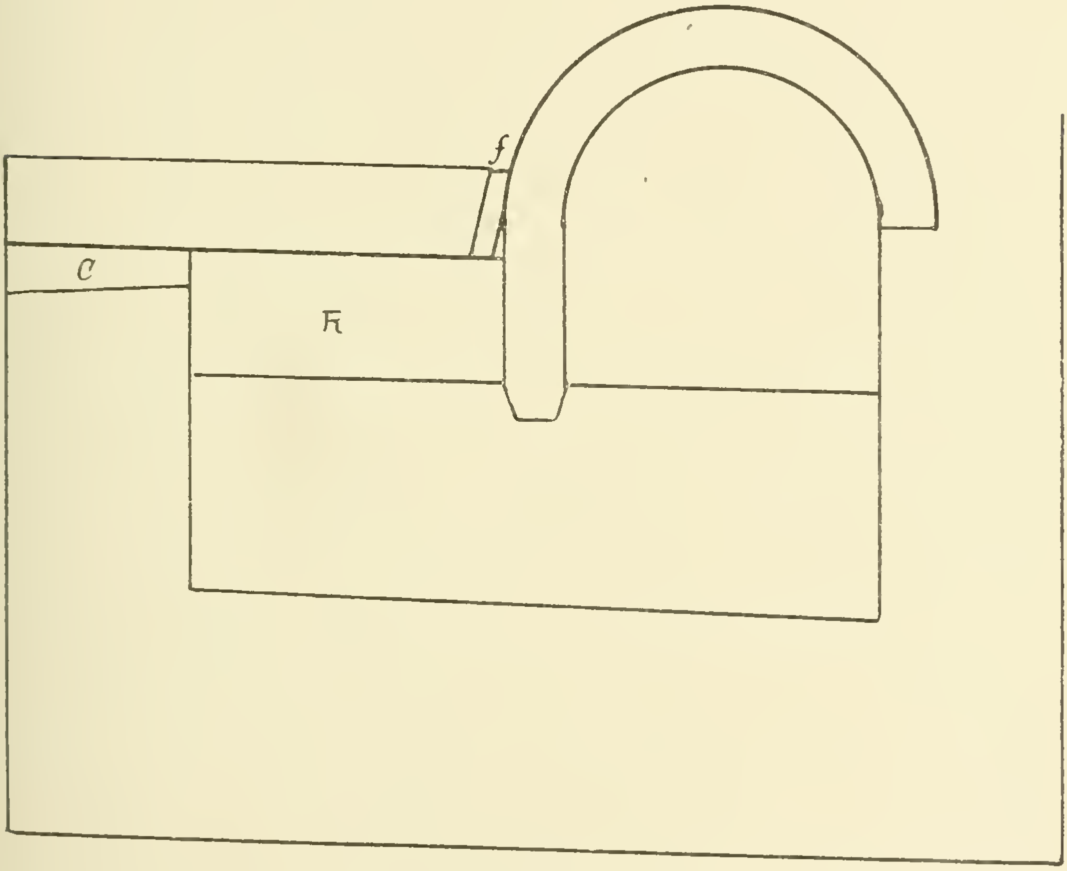

fig. 2

then the working of the retort, repeated as many times as it contains retorts. (See Fig. 1.)

The retort is supported at both ends; it rests on a narrow ledge at the back end, which is closed, and projects a few inches over a broader shelf at its front and open end. This shelf also gives some support to the condenser when it is fixed in the mouth of the retort.

In general this retort is filled and emptied once every 24 hours. Its outside dimensions are about as follows: Length 4 feet or 120 centimeters, diameter 10½ inches, or 26 centimeters. The condenser is about 24 inches long, or 60 centimeters, 7¼ inches, or 18 centimeters diameter at the largest end and 4 inches, or 10 centimeters, at the smaller end.

The retort will hold 45 pounds of roasted ore with the required amount of reducing coal.

While all of the retorts in the same furnace are of the same general design and differ very slightly in actual dimensions, they do differ very greatly in their position in the furnace. It is seldom, now-a-days, that one can see more than five (5) retorts in a vertical row, but I have seen nine (9) ranged one above the other. To visualize the operation of charging, one must keep in mind the relative position of the retort and the workman, for the charge is thrown off the end of a scoop with a 3½-foot iron handle, and in order to reach the back of the retort it must be thrown with considerable force. The pitcher's task in early days of baseball, when he was called on to deliver balls over the plate, at any height, from "ankle high" to "as high as my head," was an easy one compared with that of the charger who delivers accurately into all the retorts, and the antics of the present day pitcher do not exceed the gymnastic contortions which charging requires. When the retort is full, with the exception of 2 or 3 inches of its open end, the condenser is inserted.

The operation of luting the joint is also an expert job. A man with a big lump of wet clay in one hand walks along in front of the furnace; with the other hand he tears off smaller masses which he rolls into balls which he flips or snaps, as if they were paper spit balls, at any sign of a crack between the retort and the condenser.

When no opening appears he is ready to seal the joint. This he does with a tool like a half-moon branding iron at the end of a long handle. The branding iron is hot, and with it he circles the condenser as carefully as a cattle brander follows out the marking of his brand.

The retort is now charged, but in 24 hours it must be emptied, this seal broken, the condenser taken down, and the red hot charge pulled out. This requires a variety of tools, bars and hooks of various sizes and lengths, but the operation is a trying one in spite of fire screens now generally used. To some extent this operation has been simplified by the use of a steam jet, such as employed to blow the soot out of the flues of a fire tube boiler, but since the back end of the retort is closed, the cinders must come out at the front.

Between the filling and the emptying of the retorts there are three or four drawings of metal. With rich ores these will average perhaps six to eight pounds. The tools used for drawing are called scrapers and resemble the spoons with which a hand driller cleans out a dry hole. The metal drops into a ladle which passes from retort to retort. In a general way three men for each 12-hour shift can tend sixty (60) retorts.

That is the labor part of the work; now for the fuel part of it. The heat required for reduction, which, by the way, is very considerable, will now be considered.

The retort is, of course, heated from the outside by flames playing around it. This heat passes first through 1¼ inches, or 3 centimeters of fire clay. This, as you know, is not a good conductor, but the retort does not become quite cold in the operations of emptying and filling, so there is some heat to start with. The moist charge is the next obstacle encountered. Through this to the center of the charge, four inches, it penetrates slowly, gradually expelling the moisture and raising the temperature of the charge. When an average temperature of 1050 to 1100 degrees centigrade is attained, reduction of the zinc oxide begins.

In this reduction equal volumes of zinc gas and carbonic oxide gas are liberated. These mixed gases make their way together through the loosely packed charge to the open end of the retort, when they emerge into the condenser, where most of the zinc condenses, the carbonic oxide, not being condensable, passes out at the end of the condenser.

This is the life history of the retort, which, as I have said, is the unicellular structural unit of the furnace. But, fortunately, the life of the furnace is not the same as the life of the component cells, for the life of a retort is usually from two or four weeks. Unfortunately, the renewal of a worn-out cell is not an organic automatic operation. It requires in each case something very like a surgical operation to cut out the no longer functioning organ and transplant a new one, which involves, of course, a period of rest for this inserted organ before it can be called upon to do its share of the furnace work.

But enough of these anatomical horrors. I think from this mental picture, which was to give us a starting point from which to estimate, how far the smelter can advance to meet the ore producer in the matter of higher prices for his raw material, we must conclude that the present smelting charge is not excessive, in view of the manual labor involved in the multiplicity of manipulations to which the ore is subjected in the operation of getting the zinc out of it.

But this picture of present practice was also to serve as a background against which to contemplate any possible improvements, and to fix a starting point from which to measure and to judge any contemplated change.

Into this stage setting which I have painted for you I shall step with the natural diffidence of a "patent Process Man," and I will ask permission to make another drawing on your blackboard.

This is also a retort, the structural unit of a zinc furnace; it is a simple cell. In this case, however, the furnace is not evolved by reduplication of the cells, for the furnace is unicellular. The cell itself, however, may be very considerably enlarged without the serious impairment of its proper working. (See Fig. 2).

The cross section of the retort is rectangular, instead of circular or eliptical; its general shape is not cylindrical. It has the form of a parallelopipedon lying flat; that is, with its two longer edges horizontal. It is not mono-clastic, homogeneously moulded to shape; its walls are made up of separate pieces laid together and properly connected.

As I have drawn it, the interior dimensions are as follows: Length 7 feet, width 20 inches, height somewhat less. The opening of this retort is on one of the longest sides, and leads to the condenser. It is a narrow slot and is marked by the letter C. The opposite side has no opening and corresponds to the butt of the cylindrical retort which rests on the ledge of the middle wall of the older forms of furnace. This retort is not suspended by the ends, and is not to be encircled by flames. On the contrary, it rests on a very solid foundation and is very carefully insulated on five of its six sides. You will notice that on the side next to the condenser its walls have a thickness of about 12 inches. Its top is about half as thick, and its bottom is much thicker. You will notice that the side of the retort opposite to the condenser, the side that corresponds to the butt of the Belgian retort, is deeply rabetted into what appears to be a lining over the bottom of the retort. You will also notice that this lining extends beyond this rabbet for a distance equal to the distance from the open end of the retort to its butt, or even for a greater distance, and that the bottom of the retort and the foundation on which it rests goes equally far. Beyond this lining there is a thick vertical wall, which is joined in construction with extensions of the smaller faces of the rectangular retort.

This lining is a pool of molten metal of copper or some zinc alloy. This pool is sustained by the strong foundation and the heavy enclosing walls.

The rabbeted joint, where the back wall of the retort is countersunk into the bottom lining, is a metallic seal of trapped molten metal, which makes this side of the retort impervious to the passage of any solid liquid or gaseous substance.

I have shown, so far, only a single opening from the retort. There are others, namely, a row of inclined shoots marked F. These have in cross-section the smaller dimensions of a brick, say 2½ by 5 inches. These are tightly closed. They come through the roof of the retort, next to the wall farthest away from the condenser. There are openings in the other two sides of the retort; these are also tightly closed.

A zinc smelter has been called a mud-dauber, and knows how to stop an outside crack.

Now as to the method of heating the contents of the retort. The heat must be conducted through the walls; in this retort it is conducted through the copper lining of the bottom. It is imparted to the extended lining beyond the rabbeted joint and is conducted through the bottom below the trap, and is given up to the charge at every point on the bottom of the retort.

Under ordinary conditions the heat conductivity of copper is about 300 times as great as the heat conductivity of the material of which ordinary retorts are made. That is to say, through the same sectional area 300 times as much heat will be conducted by copper as is conducted by clay retorts through the unit distance, in the unit of time. Or otherwise, through the same section in the same time, the same amount of heat will be conducted through a wall 300 times as thick of copper as of fire clay. In both cases, of course, it is assumed there is the same difference of temperature between the two sides of the wall.

As to the charge in the retorts, ideal conditions would be a pure zinc oxide and an ashless reducing carbon; there would then be no residues. Two solids would be introduced and two gases would issue from the retort. With fairly good coal and ordinary grades of sublimed zinc oxide these residues will be light and in small amount. They can be swept off from the copper lining by a brush, like the air brush used in compressed air carpet cleaning.

This brush would be introduced through one of the side openings and the scoria would be blown out at the other, which communicates with an ashpit, like the cellar ashpit serving open fire places in city houses. The brush would use, instead of air, a small current of carbonic oxide, withdrawn by a centrifugal fan from the stream of this gas issuing from the condenser. This gas will be nearly pure carbonic oxide, which is formed in the reaction between the zinc oxide and the carbon in the charge. It has a high calorific value, but will not oxydize the zinc vapor remaining in the retort. The ratio of the carbonic oxide formed to the zinc reduced being by weight as 28 is to 65, by passing it through a meter as it comes out of the condenser a volumetric record can be obtained of the actual progress of zinc reduction.

Following the older practice, it should be possible to detach the condenser from the mouth of the retort. The duty of the condenser will correspond to what is required of the Belgian condenser during the hours of most rapid distillation; the gases entering it will be the same in all particulars of percentage, composition and temperature, so that the proportions of the condenser can be approximated to, from past experience. It will be found by calculation that sufficient volume and surface for condensation can be provided in a practicable self-contained structure, movable on wheels or rollers, out from its connection with the retort, following the analogy of a separate foreheath used with matting furnaces.

In the absence of experimental data on heat conductivity at high temperatures, it would be rash to hazard an estimate of the daily output of such a retort as I have described. But having in mind the latitude there is for varying the longest dimension of the retort, without changing the distance through which the heat is conducted, or the distance the zinc vapors travel to reach the condenser, and our ability to vary the section through which the heat passes, it is not unreasonable to expect an output of 10,000 pounds every 24 hours.

With the time required to fill and empty the retort, and that required in the preliminary heating up, cut out, the retort would be working at its maximum capacity all of the time, that is, more than three times the average working time of the older furnaces.

As I shall show, when describing how the retort is fed, the ore is delivered at once against the hot bottom of the retort, so that it is all reduced in contact with the bottom. Reduction of zinc oxide by carbon is strongly endothermic, refrigerating, so that if the ore is fed too rapidly it will chill the metal bottom. The feed must be regulated to suit the rate at which heat can be imparted to the extension of the bottom.

It is desirable to keep this at 1500 degrees centigrade. A drop of 460 degrees centigrade would reduce the temperature of the bottom within the retort to 1040 degrees centigrade, which is as low as it ought to go. But this matter of temperature will in a measure regulate itself, for when reduction ceases the temperature will quickly rise within the retort.

The ore is fed in tabloid form; that is, in compressed briquets made up of ore and reducing material in the required proportions. These tablets will be dropped through the openings F, and, as they are lighter than the metal beneath them, they will float on its surface and distribute themselves over the bottom of the retort, pressing with their weight onto its surface.

These briquets are administered as often as required, even several times a minute, and, as they will be fairly dense, they can be introduced nearly or quite red hot, so that their chilling effect will be reduced to a minimum.

It is worthy of note that with the recovery and utilization of the carbonic oxide gas issuing from the condenser, it will be a simple matter to wash out of it and recover the small percentage of zinc which escapes condensation. This is a problem which has baffled many an experimenter, as is evidenced by the hundreds of mocking tongues all tinged with the color of burning zinc which issue from the open mouths of the condensers, where the carbonic oxide is lighted as a sign to the furnace man that the condenser is not choked.

As to the best method of imparting heat to the extended lining of the retort furnaces, this will depend, of course, on local conditions. As a first step a light arch is turned from the outer wall back to the wall which forms the closed end of the retort. A chamber is thus formed, which will serve either as the hearth of a reverberatory furnace, as a flue for the passage of entirely burned gases, or as a combustion chamber in which gas, hydro-carbon vapors, or pulverized fuel can be burned, to impart heat to the metal below the arch.

The weight which this covering arch will have to carry is simply its own weight and that of the lighter insulating material which will be used to economize heat, so it will present no structural difficulty.

Recalling the fact that in the working of this furnace heat is imparted to the bottom lining over part of its area, and is withdrawn for reduction from another part of this area, calling the first the receiving and the other the delivering area, it is apparent that for a given set of conditions there must be some one proportion between these areas which will give the best results. With changed conditions this proportion will evidently vary, but certain general limitations can be put on the magnitude of this variation.

The higher the temperature which can be maintained under the arch and imparted to the receiving area, the less of this area will be required.

On the other hand, since any extension of this receiving area in the line of direct transmission of heat to the retort (the only way this area can be increased proportionally) moves its center of gravity half this distance, and therefore increases the distance the heat must be conducted an equal amount, it is evident that we can only get the advantage of one-half of the increase receiving area, which we would get if the distance the heat is conducted remained constant.

As to the thickness of the bottom lining, the depth of the pool, the amount of copper required, general limitations will control the variations. Its depth evidently controls the area of minimum cross-section through which heat is conducted. Its mass determines its heat storing capacity at any certain temperature, and therefore determines to what extent it can serve as an accumulator and equalizer of heat.

Also, under conditions in which this lining will deteriorate by fouling, the greater its mass, the greater will be the intervals between enforced renewals. These considerations favor a thick lining. On the other hand, first cost, expense of renewal and time required to bring the furnace up to working temperature, indicate a limit beyond which it is not desirable to go.

Admitting, then, that among the new ores discovered at Leadville, there may be some which cannot be utilized by methods of concentration at present practiced in this field, and agreeing that fire concentration justifies hope that present metallurgical requirements may be met, I hope we may have gone a little further in each other's company, and that you share with me the belief that it is possible for metallurgists, by modifications in their present practice, to reduce their expenses and join hands with the miner in the solution of the problem which is the utilization of lower grade ores.

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THE OCCURRENCE AND ORIGIN OF NITRATES IN COLORADO SOILS, SOME OF THEIR EFFECTS, AND WHAT THEY SUGGEST.

By Wm. P. Headden.

Read at the Meeting of the Society, October 7, 1911

The questions pertaining to the source of nitrogen in plants have engaged the attention of agricultural chemists for many years, and are not yet fully solved. The world's supply of nitrates has already come to be considered with some anxiety, not so much because of their importance in the manufacture of explosives, etc., as because of their relation to the production of food for both man and beast. The increasing rate in the consumption of Chile-saltpetre justifies the consideration of the time when these deposits shall have been exhausted and fully justifies our satisfaction at the successful establishment of methods for the manufacture of nitrates or nitric acid by means completely in our control. We can scarcely realize the immense quantities used annually in commerce, roughly two and a half millions tons of the South American product, but this is small compared with the total amount used in growing the food consumed in the same time. The methods of producing nitrates artificially are violent; the natural methods whereby immensely large quantities are produced annually do not command our attention by any spectacular manifestations, but are, nevertheless, effective. So quietly do they proceed that we have not yet found a perfectly satisfactory explanation for the formation of the South American deposits. This fact is indicated by the variety of explanations offered.

The theories suggested aim at a reasonable explanation of the source of the nitrogen necessary for their formation. One theory assumes it to have been derived from seaweeds; another from the droppings of birds; another from the dung of animals; and still others from the atmosphere by the agency of the electric discharge or through that of inorganic salts.

In regard to the distribution and supply of nitrates, we have very generally accepted it as beyond question that each generation of plants and animals have, by their death and decay, contributed to the supply of nitrogen to be made available for the use of succeeding ones. The agents which elaborate and prepare this nitrogen for subsequent use have been shown to belong to the lower orders of plants. During the past twenty-five or thirty years the students of this subject have described the agents and explained in a most satisfactory manner the processes by which this nitrogen is prepared, so that students in the class room consider questions which were unknown to the learned of two generations ago as definitely settled and the solutions thereof as common property. At one time, as is generally known, it was argued that plants could avail themselves of atmospheric nitrogen to build up their tissues. This view was combated by the experimental demonstration that certain plants do not avail themselves of such nitrogen. It has been shown that both parties were right in their facts. Some plants, the clovers for instance, do and others do not avail themselves of atmospheric nitrogen. But even this statement needs an explanation before it becomes a truthful representation of the facts. It has been shown that certain organisms which make their homes upon the roots of legumes enable the latter to obtain a large portion of the nitrogen necessary for the building up of their tissues without taking it from the soil, so that we can gather large crops of these plants very rich in nitrogen and at the same time leave the soil richer in this element than it was before we grew and harvested the crop. All this has been satisfactorily explained by the presence and activity of the little plants which make hosts of these legumes, and the two together in some way use, or as we say fix, the atmospheric nitrogen. Again, since the early eighties it has been shown that soil without a growing crop may, when kept under proper conditions, show an increase in its nitrogen content. This too has been explained by the discovery of low forms of plants which, without the aid of higher plants, are able to appropriate atmospheric nitrogen in the building of their tissues. Most of the higher plants, we may say all of them, for it is a question whether the legumes even can appropriate atmospheric nitrogen without the aid of their so-called tubercles, require that their nitrogen shall be supplied to them in combination, preferably as a nitrate, possibly also as ammonia. These lower ones to which we here refer are capable of appropriating the atmospheric nitrogen without the aid of the higher plants. A luxuriant growth of such plants would result in an actual increase in the nitrogen contained in the soil. One of the conditions for their growth, however, is that the soil must be at least neutral, or, better still, alkaline in its reaction, but certainly not acid. Such are the conditions which we meet with in Colorado soils.

The most of us are accustomed to think of the soil as dead, simply composed of rock fragments, water and the lifeless debris of former vegetation, while in fact it is the theater of very great activity, which affects our welfare directly and seriously, determining the success or failure of our crops, and whether or no the result of our labors shall be a profit or a loss. To make it plain that there is nothing sophomoric in this statement, and further, that such a matter might be a very serious one, permit me to suggest the possibility of the concurrence of two processes, fixation and nitrification, each dependent upon the activities of such plants. Suppose an excess of certain products should accumulate in the soil, for instance too much nitrate, be it of soda, lime or magnesia. What would be the result? Too much is a relative term, and if we understand thereby an extreme amount at one time, it is a matter of common knowledge that the results would be disastrous to most of our crops. There have been but few or no experiments made to determine the effects of excessive quantities of nitrates upon trees or other plants, except such as have been made by accident rather than for the purpose of ascertaining and describing these results. One good reason for this is that the occurrence of such quantities of these salts in arable lands has not been seriously considered. Too much may not necessarily mean a fatal dose. Some plants can tolerate very large applications of nitrates without succumbing and still as a crop for profit they may be seriously injured. I tried the experiment of putting considerable quantities of nitrate of soda, from five to twenty-five pounds, about small apple trees; these quantities produced various degrees of injury, even to killing one of the trees. It is generally conceded that the application of nitrates to the sugar beet produces a beet which works badly in the factory and is apt to be lower in its sugar content than beets grown under otherwise like conditions. It is a fact that the growers, with the consent of the factories, are now using larger quantities of nitrates than formerly, up to 400 pounds per acre, applied before the first of July. What would be the effect of the formation of a like quantity of nitrates in the soil say in August or September, if such a thing be possible? The answer is, a green beet of undesirable qualities—lower in sugar than it should be and an expensive one to treat. The formation or accumulation of too large a quantity of nitrates in our soils would threaten the lives of our orchard trees, the profits of our sugar production and the quality of our crops. The question that I wish to present is not merely one of scientific interest, but of the very greatest economic significance to the people of this State. Complaint is constantly made that whereas the beets produced a few years ago were very satisfactory, those produced now are lower in sugar, though the beet itself has in the meantime been greatly improved by breeding, and we have had the benefit of years of experience in cultivating the crop. Another complaint is concerning the irregularity in the yield and quality of the beets from the same field without such a variation in soil or other conditions that the cause can reasonably be sought in such facts. I was kindly furnished with some samples of beets in the fall of 1910 which had received excellent care and were in every way satisfactory, except that the yield was ten tons per acre, which was less than was expected. The percentage of sugar in these samples was 18·3 and the purity 83·2. We had samples of beets from other fields in the same vicinity which had received good cultivation and which were grown on excellent land. These beets never showed more than 13·3 per cent sugar, and the highest purity was 79·6. The land in the former case had been in beets for five consecutive years and had received no fertilization, that in the second case had not been in beets for more than two years, though it had been under continuous tillage for several years. The question confronting us is why there should be such differences in beet crops when grown under good conditions of weather, soil and culture? Why was one crop ripe and the other green when harvested October 17? The beets in a certain section of our state averaged very satisfactorily in the late nineties of the preceding and the first three years of this century, around 17 per cent, but they have fallen till the average quality is no longer good. The people have now had at least ten years experience in growing this crop on a commercial scale, and have had the supervision and advice of specially trained men, so that the poorer quality of the beets now can neither be attributed to ignorance of cultural methods nor to indifference on the part of the grower, nor yet to the quality of the seed. Whatever may be the cause of this, it is a matter of great importance to the welfare of the interested communities. The falling off may be taken, for the purpose of illustration, as 3 per cent, and a reasonable aggregate crop for the section is 500,000 tons, or one billion pounds. In this case the loss would be 30 million pounds of sugar. If this sugar were worth 1¼ cents per pound to the growers, the loss would amount to $375,000. This statement does not consider any factory problems whatsoever, simply the loss on the raw sugar in the crop. In the estimated $375,000 loss on a 500,000-ton crop, no consideration has been taken of the factory losses, without which we have only a partial presentation of the matter. The greater portion of the total loss to the industry lies in the increased cost of manipulation, in which I include all of the evils attendant upon the bad quality of the crop. The factory does not pay for the loss in percentage of sugar, the grower loses this, but the factory pays a high price for the sugar that it recovers, incurring a loss in the supposed case which we may reasonably estimate at $700,000.

Many letters have either been addressed directly to the writer or referred to him, complaining that certain portions of land would produce nothing. Something over two years ago I was asked to examine a piece of land set to orchard. The conditions, in my judgment, were very bad indeed. The owner was anxious, and he had great cause to be. I have made these statements not for the purpose of exciting misgivings, but for the purpose of presenting the fact that I am fully convinced that the importance of this matter is so great that we owe it to the scientific world, while avoiding any rash statements, to make known the results of these investigations.

It is now a little over a year since Bulletin 155 of the Colorado Experiment Station was published, followed a little later by Bulletin 160. In these two bulletins were set forth some facts and the writer's views in regard to their cause, which have been considered as somewhat radical, if not sensational and revolutionary. We recently published two other bulletins on the same general subject, *i. e.*, The Fixation of Nitrogen in our Colorado Soils, etc., Bulletin 178 by the writer and 179 by Prof. W. G. Sackett. It is my intention to set forth only such facts as I hope may be of interest from a scientific standpoint. I do not, however, wish to disguise the fact that I am deeply interested in the purely agricultural features, or rather in the agriculturist whom it affects, for I am loath to acknowledge that there are any purely scientific features, as distinguished from purely agricultural ones, involved.

The beginnings of this investigation were not characterized by a systematic and definite order of observations. The fact is that I was studying a related subject, and it was the observation of isolated and apparently inexplicable facts which did not articulate with anything that I had ever seen, either in the field or in print, that constantly challenged me to further investigate them. Year after year I had received letters about "black alkali." I had invited the public to send me samples of this salt and persistently declared my conviction that this alkali, sodic carbonate, did not occur in our so-called alkalies in injurious quantities. The "black alkali" was never sent to me, only now and then an indifferent sample of soil, an aqueous extract of which would be examined for the presence of sodic carbonate with indifferent or negative results.

At last, thanks to the facile pen of some local geologist, I had an opportunity of seeing a number of oily "brown spots on which nothing would grow," the familiar complaint of numerous correspondents. An analysis of the soil from these spots was a veritable revelation. The air-dried surface soil yielded to water 13·4 per cent of its weight, 41·859 per cent of which consisted of the nitrates of calcium, magnesium, sodium and potassium. This soil was from native prairie land, *i. e.*, land which had never been cultivated. The only answer which I could give to the ever-recurring questions, whence came these salts? how can it be true? was the answer of every honest and open mind in like conditions of surprise and ignorance, *i. e.*, "I don't know." As the land in question happened to be in a country where sheep had been grazed, I canvassed the possibility of this condition having been brought about by the decay of carcasses at these points, but there were no bones or other signs that such had ever happened at these spots, besides the spots were mostly round or elliptical and some of them were quite large, say 12 feet in diameter, while others were very small. I then recalled barley and grain fields with similar areas, around the edges of which there was a luxuriant growth, a phenomenon entirely compatible with the presence of nitrates. I had in my possession samples of soil in which barley had not thriven, but it betrayed no hint of any ordinary cause for such conditions as actually existed. Examination revealed the presence of comparatively large quantities of nitrates. It was evident that the occurrences were too general and the individual spots were too large and varying in size to be accounted for by the decay of the carcasses of sheep or even of cows. Another patent question was, why are these spots brown, almost black, and oily in appearance? As many of the "brown spots" mentioned as occurring in the native prairie sod were occupied by colonies of ants, one colony to each spot, I tried to explain the color by attributing it to the ants, but as there were spots which were not, at that time, occupied and which showed no indication that they had ever been occupied in this manner, the ants could not be the cause of the brown color. The situation had developed three questions: 1st, are all of the "brown spots in which nothing will grow" similar to these?; 2nd, whence came the nitrates?; 3rd, why are they brown? These questions have been answered in the order here presented.

All brown spots cannot be qualified as these have been by the attributive, "on which nothing will grow," but the complaints agree in this, so there is something peculiar to these spots. Several years subsequent to the taking of the samples of which I have stated that 41·859 per cent of its water-soluble portion consisted of nitrates, I observed an area of several acres in one body which was brown and looked wet on the surface, but was in reality dry and even mealy in places, quite generally so under the slight crust which covered the surface. This ground was brown and barren. There were three distinct parts in this case: the crust, the mealy portion and the soil proper. The crust contained 12·52 per cent soluble in water, of which 19·822 per cent was sodic nitrate; the mealy portion contained 8·44 per cent soluble in water, of which 15·42 per cent consisted of nitrates; while the first foot of soil gave 6·5 per cent soluble in water, of which 43·58 per cent consisted of nitrates. These samples proved typical of a great many others from a very considerable section of country. Another section of country is represented by the following surface sample, taken from land which had also become brown and barren. This yielded 5·42 per cent of water-soluble, of which 50·22 per cent consisted of the nitrates of sodium, potassium, magnesium and calcium. Still another sample taken from a similar brown area where nothing was growing gave 4·518 per cent soluble in water in which the nitric acid corresponded to sodic nitrate equal to 38·867 per cent of the water-soluble, or 1·756 per cent of the air-dried soil. These are only a few samples given to answer our first question, are the brown and barren spots complained of in various parts of the state similar in character? A study of several hundred occurrences distributed over nine counties of the state shows that they all contain an excess of nitrates, the maximum quantity indicated by any sample being upwards of six per cent of nitrates calculated on the air-dried soil. These nine counties represent some of the best portions of the state. The altitudes at which the occurrences have been met with range from 3,300 to 7,500 feet. These occurrences, then, have, so far, the following characteristics in common: the brown color, the oily appearance, partial or total barrenness, the presence of nitrates in very unusual quantities and a property not heretofore specified, but described as a muddy condition of the soil. This characteristic was described in Bul. 155 and led very naturally to the question of what part seepage may play in this problem and whether the barren condition of the soil may not be due wholly to an excess of water rather than to the presence of the nitrates. As seepage in our country is invariably associated with the alkali question, a familiar one in all irrigated, arid or semi-arid countries, the question of what part these salts may play would appear to be directly involved. There is no doubt but that these questions present difficulties and require almost as many solutions as we have various soil conditions, including the alkali. In this connection it is to be remembered that our alkalis consist of the sulfates of sodium, magnesium and calcium, with smaller amounts of sodic carbonate and chlorid. The statements frequently made and universally accepted pertaining to the effects of sodic carbonate do not apply to our soils, and ordinarily the question of the water passing through otherwise pervious soils would not be interfered with by the amount of sodic carbonate usually present in our alkalis.

The salts actually present in our soils sometimes exceed the limit of tolerance adopted by some authors, and it may be that some damage may have been done by these salts, but I have personally never seen a single instance of injury done to a tree or to vegetation which I was convinced had been done solely by these salts; it must be remembered that sodic carbonate is practically absent. I have seen some trees, patches of alfalfa and other crops injured by water, but in my judgment an excess of water has had little or nothing to do with the killing of the trees in any case described or referred to in this paper or in either of the bulletins published on this subject. The highest water table, found in any case, one simply referred to and not described, was 4½ feet below the surface, quite a sufficient depth for the growth of trees that do not push their roots deeper than two and a half feet into the soil. Both points, however, are more conclusively answered by direct observation, *i. e.*, that the evils attributed to the nitrates are not confined to lands which involve these questions, and consequently eliminate them, even in these cases, as the agents causing the trouble. We find, for instance, sandy soils underlaid by coarse gravel, located beside a river and twelve or fifteen feet above its bed, loaded with these nitrates, and the trees and vegetation killed. In these cases the trouble is not due to an excess of water. Again we find orchards that have grown thriftily for fourteen, sixteen and even twenty-eight years, perishing within six weeks. It is scarcely possible to conceive of old established trees occupying thoroughly well drained ground succumbing to an excess of alkali or water in such a manner. Further, we have found this difficulty, to be more fully described later, in ground whose surface foot of soil contained a lower percentage of soluble salts than has been found permissible in the top four feet. These considerations answer the questions relative to the part played by either excessive water or excessive quantities of our ordinary alkali salts, either alone or in conjunction.

We have referred to a condition of the soil designated as muddy, by which we certainly understand a wet condition.

We recognize that it is incumbent upon us to answer if we can why it is muddy if it be not due to water. We do not say that it is not due to water, but simply that it is not due to a high water plane, for in the very worst cases of muddy grounds we did not find a proper water table at depths of six and six and a half feet respectively, though the ground was muddy at two and a half feet. I know of one place where this condition has persisted for at least four and a half years and continues at the present time. Such a condition is a very unusual phase of seepage, if it comes under the ordinary conception of it at all. I think that six or six and a half feet would be considered a safe depth for the water table under all conditions. As stated, we have no carbonate, or only a small proportion of it, in our alkalis, many samples of them being practically free from it, and the deflocculation of the soil which makes it so retentive of water cannot be attributed to the action of this salt. The use of sodic nitrate has been observed to bring about a puddling of the soil, and is probably the cause of this condition in these cases.

Drowning does not kill trees suddenly; besides, very many trees have died in land which was not wet, so excessive water *per se* is not the cause of the trouble. Likewise many trees have been attacked and even killed where there is neither an excess of water nor of the alkalis, while, on the other hand, there are many healthy orchards growing on lands which are decidedly rich in alkalis; hence we conclude that the trouble, especially with trees, is not due to alkalis *per se*. The same facts prove conclusively that the trouble is not in fact due to the joint action of the two. We wish to state distinctly that lands may be seeped and trees and other land plants may be drowned by a continued excess of water in or on the land, and likewise that trees and other plants may be killed by an excess of sodic carbonate and the other salts present in our so-called alkalis, but we have been unable to find any proof that they, either separately or in conjunction, have produced the damage here alluded to and fully described in the publications of the Experiment Station.

In this place it may be proper to state briefly the general character of our ground waters and alkalis. It is evident that the ground waters, as well as the alkalis, will vary exceedingly from place to place, so in this paragraph we will consider only such as are typical of the ground waters in general, of which thousands of samples may be gathered from as many different localities. Exceptional ones, of which perhaps the whole state would furnish not more than two or three different occurrences, and ground waters from areas in which we know that unusual conditions exist, will not be considered. I shall use for the present purpose the ground water from an undrained piece of alkali land belonging to the State Agricultural College. I take this because the land was very rich in alkali and because it was studied systematically for several years, during the whole of which time it was under cultivation. The general composition of the salts held in solution by this ground water is fairly represented by the following percentages: calcic sulfate, 30-40; magnesic sulfate, 20-30; sodic sulfate, 12-20; sodic carbonate, 5-10; sodic chlorid, 5-10. The total solids in the ground water when the wells were first opened ranged from 160 to 345 grains per imperial gallon, or from 2,286 to 4,921 parts per million. The nitric nitrogen in these waters before irrigation varied from a trace to 0·600 p. p. m. The drain water from similar land in the same section of country carried from 0·24 to 0·28 part of nitric nitrogen per million. This particular section, however, has never shown any trouble such as forms the subject of the study presented by the publications referred to throughout this paper. The results obtained in analyzing the waters from surface wells in many sections of the eastern slope of the Rocky Mountains justify the assumption that these waters are fairly representative of ordinary ground waters in our alkalized sections. We can further give results obtained with some ground waters collected in the immediate neighborhood of, but not beneath a nitrated area. These waters differed from the preceding only in containing large percentages of sodic chlorid, but contained no nitrates. Some of the residues obtained by evaporating these waters gave no satisfactory test for nitric acid when tested with diphenylamin and sulfuric acid. Such waters cannot be the source of nitrates by rising *en masse* or by capillarity, and subsequently depositing the salts on evaporation. These lands are, it is true, often irrigated, and some salts may, in exceptional cases, be deposited in and on the soil through this agency, especially if the water used for irrigation should be seepage water taken directly from a cultivated area. Throughout the state evaporation is very high, and such seepage waters might yield nitrates to the soil, but the use of such waters is quite exceptional and wholly negligible in this discussion. I do not actually know of a single instance in which such waters are used on a large scale. A considerable number of irrigating waters have been examined for the presence of nitrates, the amount of which has been found to be very low, ranging from a trace in some of the stored or reservoir waters to five-tenths part per million as a maximum in river waters. If we should evaporate two feet of such river water on an acre of land, it would add to it 16½ pounds of sodic nitrate. The very highest figure for nitrates found in return waters, sample taken near to a town, was 1·5 parts per million, which would correspond to only 49½ pounds of sodic nitrate for each two acre-feet of water. These quantities are wholly insignificant compared with those with which we meet in our soils, where as much as 4,400 pounds has been found in the top two inches, and the case referred to is by no means an isolated or an extreme one. Moreover, it represents acres of land, and not an area of a few square feet.

There is a theory whereby we account for the accumulation of salts in low areas by supposing that the salts were washed from higher lands by excessively heavy rains and deposited in the low places by the process of evaporation. This undoubtedly applies to some of our alkali areas which a novice would recognize, but not to the nitre areas here discussed. The very first instance of the occurrence of these nitrates given exhibited a series of spots in a level area in which we have most remarkable quantities of nitrates, upwards of 5 per cent of the surface soil, while the adjacent soil was as poor in nitrates as other virgin soils. Some samples of virgin soil from the plains have given as much as 8·0 p. p. m., or 0·0008 per cent of nitric nitrogen as a maximum. Concentration of these salts, due to the transporting power of heavy rains or percolating waters, and subsequent evaporation, cannot apply, for we find these nitre areas appearing, growing larger from month to month and exterminating vegetation in sandy well-drained soil, close to a river into which any floods of this sort would carry their burden of salts and probably the land as well.

What we have already said about the absence of nitrates in the alkalis, the soil, the ordinary ground, river and other irrigating waters, to which we may add well and spring waters, is a sufficient answer to any suggestion that the nitrates here considered might owe their origin to nitrates in some rock stratum. If further answer to such suggestion were needed, we would readily find it in the wide distribution of these occurrences absolutely independent of geological horizons.

I had gotten this far in my inquiry about two and a half years ago, and was fully convinced that none of the sources or agents usually supposed to account for the collection of alkalis within certain areas were applicable to the accumulation of these nitrates; besides, the occurrence of these nitrates and their rapid increase can scarcely be considered as similar to those of the alkalis. These nitre areas are almost always of a brown color, varying from a light brown to almost a black, and are oily or wet in appearance, while in fact they are really quite dry. It is distinctly to be understood that not all soils having a dark color and appearing wet are nitre soils, an excess of calcic chlorid in a soil may impart to it a dark color and a wet appearance; but the converse is true, *i. e.*, that all nitre areas are stained more or less deeply brown if not cultivated, and sometimes even when cultivated, and appear oily or wet. I know of but one exception to this statement, in which case the ground has always been so dry when I have seen it that it has at all times seemed to me impossible for the facts to be as they really are. As stated, I had not proceeded very far in this investigation before I became convinced that none of the ordinary explanations for the accumulation of salts in certain areas were applicable to these nitre areas, but that their formation took place where we find them. This view presented serious difficulties, but I had as I believed considered all probable, if not possible, sources from which they might have been derived, and had convinced myself that they had not come from these sources. The nitrates were not only present, but were apparently increasing, of which fact I will give you satisfactory proof in another place. The first serious problem that presented itself may now be more clearly stated than it first appeared to me, and is as follows: The nitrogen in these nitrates is sometimes ten times greater in quantity than the total nitrogen usually present in our soils. The questions presenting themselves were: Whence came the nitrogen, and how were the nitrates formed? There remained but one source, *i. e.*, the atmosphere, and but one class of agents, *i. e.*, bacteria, which possess the power to build up their tissues by appropriating the atmospheric nitrogen subsequently to be transformed into nitric nitrogen either by these bacteria themselves or by others. These views were announced in 1909. The existence of such bacteria had at that time been known for a number of years, but the part assigned to them in this problem seemed too big and was not accepted as proven. I have endeavored to furnish direct proof. I gathered a sample of soil in which the total nitrogen and the nitric nitrogen were determined with great care and in triplicate. Of this sample four portions of 1,250 grams each were placed in an incubator after the moisture content had been made up to 18 per cent and kept at 29° C. for twenty-seven days, the dishes were weighed from time to time and water added to maintain the moisture at 18 per cent. I used distilled water which had been boiled to expel all traces of ammonia. Another sample was treated in like manner, except that the double Petri-dish was placed in a warm room, and still another, the sixth sample, which was really the original soil sample, was placed in a large bottle in the moist condition just as it was taken from the field. The bottle was only partly filled, was loosely stoppered and inverted and kept in the same room where the fifth sample was placed. At the end of twenty-seven days portions of these samples were taken, dried and a triplicate nitrogen determination made on each of them. The result was that each sample showed the presence of more nitrogen than was present in the original sample. The smallest gain was made by the original sample, bottled just as it was brought in from the field, which gained for each 100 grams of soil 4·82 milligrams of nitrogen, the maximum gain was 10·54 milligrams for each 100 grams of soil. This may not at first sight seem to be a large quantity, but by converting this into parts per million we obtain 105·4 parts, and as we consider an acre-foot of soil to weigh 4,000,000 pounds, it gives us 421·6 pounds of nitrogen fixed in 27 days, or at the rate of 5,616 pounds per acre-foot per annum. It is customary to consider the nitrogen in proteids as constituting 16·00 per cent of the total, consequently we multiply the percentage of nitrogen by six and one-quarter to obtain the proteid. Adopting this rule as applicable, we obtain 17·5 tons as the amount of the corresponding proteids. This appears to be and really is a large amount of nitrogen to be added to the soil per annum, and when calculated in percentage of the soil it amounts to 0·1404 per cent, which is an amount almost one-half more than is contained in our average Colorado soil. The former percentage, 0·1404, is the amount calculated as accumulating in one year and does not consider any changes or losses during that time, while the latter statement refers to the amount of nitrogen usually found in our soils as we sample them. It is common knowledge that nitrogenous matters suffer changes rapidly, and frequently with the loss of nitrogen. Such processes were probably going on in these samples. It is not uncommon for the destructive processes to overtake and even outstrip the constructive ones, so that measurable losses may appear. We wished to determine what would take place if we continued this experiment with these samples, so the experiments were continued 21 days longer, or 48 days in all. We found that all of the samples showed a further gain, and that the respective samples had made a total gain for each 100 grams of soil of the following amounts, given in milligrams: 12·43, 10·18, 10·60, 9·30, 12·00 and 7·9. The first four samples were kept in the incubator, the fifth and sixth were kept at the temperature of the room. The rate of gain is evidently less than during the first period, but the elimination, if any, has not nearly equalled the fixation. All questions relative to the source of energy used to accomplish this are left for others to solve, and consequently the amount of organic matter in this soil has not been investigated. I have attempted to establish the fact that this soil in its natural condition *does fix* nitrogen.

I stated that the nitric nitrogen was determined at the beginning of the experiments; it was also determined at the end of each period, namely, at the end of 27 days, and again at the end of 48 days. The longer period gave the highest rates of gain in nitric nitrogen. This gain ranged from 19·15 to 138·0 per cent, calculated on the amount of nitric nitrogen originally present. The smallest gain was in the original sample, to which no water had been added; the largest was in a sample containing 20 per cent of water at the end of the experiment. A slight loss occurred in the former sample during the second period. The maximum gain in nitric nitrogen corresponds to the formation of five tons of sodic nitrate per acre-foot or 4,000,000 pounds of soil per annum.

It will be recalled that the first spot described was black, glistening, and appeared oily or wet on the surface. Further, it was stated that the complaint has been of brown spots on which nothing will grow. We have never had any complaint of white spots, always of brown spots, and our lands turn brown as a rule before any serious outbreak of this trouble occurs. This is so generally the case that it is common for the people to state "the ground turns brown and then things die." These incubated samples, with one exception, became decidedly darker on the surface long before the end of the experiments. This brown color is not to be confused with the brown stains produced by the leachings of a manure pile or other organic matter, which it in a manner resembles. In making these experiments the soil was tested to see whether it would yield a growth of nitrogen-fixing plants, azotobacter, or not. This soil in the beginning gave Prof. Sackett a rather unsatisfactory growth, but on my request the experiment was repeated on a sample taken from the dish which was kept at room temperature on the thirteenth day of the experiment. The surface had already begun to change its color. This sample gave a very vigorous growth, which showed brown points on the surface of the membrane on the ninth day. Professor Sackett has succeeded in obtaining cultures in which the brown color was produced by the azotobacter, and has also established the conditions which determine its production. In Bul. 155, p. 46, I said, concerning these spots, "One thing is characteristic of all of them, *i. e.*, the brown color of the soil, hence the common term 'black alkali.' The dark color is possibly due to the bacterial flora itself, as the azotobacter form yellow-brown or dark brown films." Again, in Bul. 160, p. 8, "The brown color is not due to the presence of the nitrates, for they are colorless, but to a coloring matter formed by these germs." Which statements have been fully established by Professor Sackett.

These experiments are depended on to prove directly what previous investigations had indicated, by eliminating other sources from which to derive these nitrates. Previous results showed that there were no probable sources whence to derive these nitrates outside of the areas in which they occur. These experiments show that it is possible to form them where we find them. The nitrogen fixed per acre-foot per annum would yield about 17 tons of sodic nitrate if it were all converted into this form, while the nitric acid actually formed during this experiment corresponds to the formation of five tons of sodic nitrate per acre-foot per annum.

As stated, the soil teems with life, and while it is certain that the azotobacter fix the nitrogen, it is not certain how great or small a part, if any, they play in the formation of the nitrates. Other bacteria may be wholly responsible for this work, but I believe that the azotobacter participate in it, as has been asserted by one investigator but which is not, I believe, generally accepted.

My conclusions so far are that the presence of these exceptional quantities of nitrates in our soils is not to be accounted for by supposing them to have been transported from more or less remote places, in solution or otherwise, either by ground or surface waters and subsequent concentration due to evaporation, but that they are now being formed in the soil, principally near the surface, where we find them. Further, I believe that these extreme developments are of comparatively recent origin with us, and that they will probably continue to develop in our alkaline soils if not prevented by cultural or other remedial methods until the concentration of the salts exterminate the bacterial flora, which endure longer than our cultivated plants, especially trees.

In the earlier paragraphs of this paper I alluded to the effect of these conditions in general terms. I may now briefly refer to them more in detail and state my reasons for attributing these conditions to the presence of nitrates.

I have already stated the effects upon the soil as follows: The surface of the soil becomes brown and mealy, some soils are deflocculated to such an extent as to become muddy and vegetation is killed.

The most conspicuous effects are produced upon the apple tree, though the pear, peach, cherry, cottonwood, maple, Lombardy and other poplars, willow and still other trees are affected by it. The first sign of the effect is a burning of the leaves at the apices, then along the margins and finally involving the whole blade. Of course such a leaf is killed. The time required to effect this varies. In the first case of this trouble that I saw, the trees were killed outright in ten days, the leaves remaining on the trees. On very young apple leaves and pear leaves the color is black. Very many trees have died in this manner during the past two and a half years. It is, of course, very unsafe to make any estimate of the number of trees which have died in this manner, but there are many thousands of them, whole orchards having been ruined. I can describe but a few of them. One orchard in particular was an old one, trees large and thrifty, size of orchard about seven acres; soil sandy loam, perfectly drained; trouble began in 1909, when most of the trees died within six weeks after the first attack. In 1911 the orchard is entirely gone, with the exception of perhaps twenty trees. Another orchard showed the first trouble early in 1909. About eight acres of this orchard were killed. Another orchard, attacked in 1910, about six acres destroyed. Another orchard, attacked in 1910, about seven acres destroyed. Still another orchard, date of first attack not known, probably thirty acres destroyed. These orchards are not in one section, but are widely separated from one another, and represent a variety of soils. The trees in all of these orchards and in very many others died in the same manner. The surface soils of all of these orchards referred to have been tested and found to be excessively rich in nitrates. After I had come to the conclusion that the probable cause of the death of these trees was the nitrates in the soil, I made the experiment of treating some three- or four-year-old apple trees with different quantities of Chile-saltpetre, with the result that I injured every one that I treated, with one exception. I killed one tree in four days. All of these trees showed the same symptoms as the orchard trees show. I tried ordinary table salt to see if it would produce the same results, but it did not. There can be no doubt but that the nitrate in these soils would kill the trees if by any means it should come in contact with the feeding roots. This can be easily brought about by a light rain or irrigation, and probably otherwise, as the apple tree roots are practically all found within two to two and a half feet of the surface, sometimes within eight inches.

I used the beet crop as an illustration to show the importance of this subject to the state. This was done purposely, because I have experimented with this crop and have proven that the plants are very tolerant of nitrates, especially if once established, very much more so than I imagined before I began to study the subject. Suffice it for the present to state that the illustration used earlier in this paper is really more than an illustration, but it does not present definitely established facts. We have, however, succeeded in depressing the sugar content, in obtaining an objectionable shape of the beet, in protracting the growing season; in other words, preventing the ripening, and in increasing the nitric acid in the beet by the application of unusual quantities of nitrates some of it late in the season. The portion which we added before the planting of the seed benefited the crop, the second portion applied a month later also benefited it. This is entirely in harmony with the results of German practice, the application of the third portion was detrimental as were the fourth and fifth portions to even greater extents. The qualities of these beets for factory purposes were very bad. All of which will be set forth in a future bulletin of the Experiment Station.

In the opening paragraphs of this paper I mentioned briefly the various theories advanced to account for the formation of the nitrates occurring in Chile and Peru, and in all of the succeeding ones I have laid stress upon the unusual amounts of nitrates, not necessarily sodic nitrate, occurring in many of our Colorado soils, amounting in two cases to upwards of five and six per cent respectively.

The source of the nitrogen and the manner of its conversion into nitrates in India is quite well known. The explanation is at least accepted as thoroughly satisfactory, *i. e.*, the transformation of nitrogen of animal origin into nitrates by the action of nitrifying bacteria. A similar origin has been advocated for the nitrogen in the Chile salt, *i. e.*, the droppings of birds or of vast herds of animals. The presence of iodin in these salts has led to the suggestion of immense masses of seaweeds as the source of the nitrogen. Again, the atmosphere has been appealed to as its source, and the electric discharge as the means of oxidizing it. It has also been suggested that the carbonates of the alkalis and alkaline earths possess the power of inducing the oxidation of atmospheric nitrogen. The theories most seriously considered are those first mentioned, *i. e.*, those attributing the origin of these salts to the droppings of birds, or the dung of animals or to vast accumulations of seaweeds.

The facts obtaining in such large districts in Colorado suggest that the Chile-saltpeter may have had a similar origin. The theories heretofore advanced have so far as I know but a slight basis of fact on which to rest. The theory attributing the source of the nitrogen to the droppings of birds requires, as has been pointed out, tremendous deposits of this material which is rich in phosphates, but no trace of the phosphates has been discovered. The strongest point in favor of the theory attributing the source of the nitrogen to seaweeds, is the presence of iodin which occurs in the ash of these plants at least in some of the ashes.

The area in which this nitrogen fixation by the azotobacter is actually taking place in Colorado under our semi-arid conditions is sufficiently extensive to entitle the suggestion that the nitrogen present in the Chile-saltpeter was also fixed by azotobacter to serious consideration. We have found large areas in the eastern and likewise in the western portions of the state, sections about 380 miles apart. Also in the southern portion near the New Mexican boundary and within forty miles of the northern boundary, localities about 270 miles apart. It is not to be inferred that these nitre areas are continuous, but they are in fact quite extensive, in places being continuous for miles. I have stated the conditions in Colorado, but neither these nor the occurrences are confined to this state. The amounts of nitrates found are also sufficiently large to entitle the suggestion to consideration. Analyses of surface samples have shown that 6·5 per cent of the air-dried soil consisted of nitrates. The area involved in this case was not less than ten acres, and as the sample was taken to a depth of two inches we would have two hundred and ten tons on the ten acres of this land taken to this depth. In another sample taken to a depth of five inches we found 2·6 per cent of nitrates. This was from a large piece of land, forty acres in all, but assuming that only eight acres of it was as rich as this we would have one hundred and seventy-two tons in the top five inches of the land. There are hundreds of acres of land in this state which carry from one to five tons of nitrates in the top two inches of the soil. These conditions are met with at altitudes of from 3,300 to 7,500 feet.

The rate of fixation obtained by experiment, 5,616 pounds of nitrogen for each 4,000,000 pounds of soil per annum is sufficiently large to further entitle the suggestion to consideration. The nitrification obtained by experiment is also significant, *i. e.*, corresponding to the formation of five tons per acre-foot of soil per annum.

It would seem reasonable and even probable that the nitrates found in Nevada and also those found in Chile and Peru should also owe their formation to these causes, *i. e.*, to the action of azoto- and nitrobacter.

We may summarize this paper as follows:

There are large areas in widely separated portions of the state in which remarkable quantities of nitrates have already accumulated.

These areas are all characterized by a brown color on the surface, and appear oily or wet and are sometimes glistening.

The soil of these areas, especially in the early stages of the trouble, has a soft, velvety feel under the foot and later becomes mealy on the surface.

In some of the soil, such as is clayey, the soil is deflocculated, becomes muddy and retains water with great tenacity.

The nitrates accumulated in these areas do not owe their origin to the ordinary white alkali of the country nor have they been washed off of adjoining lands, nor yet have they been brought into these areas from adjoining lands by ground waters unless these ground waters flow from other nitrated areas, such as a mesa rich in nitrate spots.

These nitrated areas are not in any way dependent upon the geological formations of the country.

The irrigating waters, whether river or reservoir waters, do not contain unusual quantities of nitrates, the range being from a trace to 0·5 p.p.m.

Fixation takes place rapidly in these soils, the maximum result obtained in twenty-seven days corresponded to the fixation of 5,616 pounds of nitrogen per acre-foot per annum or of 17·5 tons of proteids.

Nitrification also takes place, the maximum increase obtained in 48 days was 138·0 per cent of the nitric nitrogen present at the beginning of the experiment, which corresponded to the formation of five tons of sodic nitrate per acre-foot, or 4,000,000 pounds of soil per annum.

All of the samples except one showed a darkening of their surfaces during the experiment.

The destruction of many orchards is due to the formation of nitrates in the soil.

The general effect of the formation of nitrates throughout the season upon some of our agricultural products, upon the sugar beet in particular, is extremely prejudicial.

The areas involved, their wide distribution throughout this state, and their probable presence in other portions of the semi-arid west, together with the rates of fixation and nitrification obtained by direct experiment, suggest the probability that the nitrates of Nevada, Chile and Peru owe their origin to the fixation and nitrification of atmospheric nitrogen by bacteria, azoto- and nitrobacter.

REPORT OF THE EXECUTIVE COMMITTEE OF THE COLORADO SCIENTIFIC SOCIETY FOR THE YEAR 1911.

Denver, Colorado, December 16th, 1911.

By the Secretary.

During the past year the proceedings of your Society show that nine regular meetings were held, with an average attendance of 26-2/3, and that nine papers were presented and read. The papers read, with their titles and authors, were as follows:

"A Discussion of Rock Streams with Special Reference to the Rock Streams of Veta Peak, Colorado," by Dr. Horace B. Patton.

"Description of a Tin Deposit in Texas," by Dr. Regis Chauvenet.

"Genesis of Ore Deposits," by Mr. George J. Bancroft.

"A Recent Trip to Honduras," by Mr. Rensselaer H. Toll.

"Asbestos Deposits of Casper Mountain, Wyoming," by Mr. Henry C. Beeler.

"The 105th Meridian and the Mile High Level, in Denver," by Dr. Herbert A. Howe.

"Eskimo Dogs, Their Origin, and an Example of Reversion," by Mr. J. D. Figgins.

"The Occurrence and Origin of Nitrates in Colorado Soils; Some of Their Effects and What They Suggest," by Dr. William P. Headden.

"Screenless Sizer," by Mr. James M. McClave.

There were nine papers published this year, the same number having been published last year.

The lowest attendance at any meeting was 14 in September, while the highest was 37 in April. The average attendance for the nine meetings was 26-2/3. In 1910 the lowest attendance at any meeting was 23 in December, and the highest was 108 in April, the average being 40.3.

During the year 24 members have been elected. The loss has been 21; 6 by death and 15 by resignation, leaving a net gain of 3. Those lost by death were as follows: Mr. Robert Forrester, who died December 20th, 1910; Mr. John E. Chapson, who died January 20th, 1911; Mr. Samuel F. Emmons, who died March 28th, 1911; Mr. James B. Grant, who died November 1st, 1911; Mr. Charles B. Kountze, who died November 17th, 1911; and Judge Carlton M. Bliss, who died November 27th, 1911.

Of the present total membership of 252, 154 reside in Denver; 46 outside of Denver, in Colorado; 41 outside of Colorado, in the United States, and 11 in foreign lands. The roll consists of 4 life members, 9 honorary fellows, 13 fellows, 173 members, 38 associates, and 15 who have not as yet been graded.

The Executive Committee held 5 regular meetings, with an average attendance of 6-1/5, besides several informal meetings.

There have been 6 exchanges added during the past year, viz.: American Brass Founders' Association, Australian Mining and Engineering Review, Colorado School of Mines, Economic Geology, Carnegie Library of Pittsburgh, and the Patent Office Library of London.

The number of visitors to the museum and library during the past year was 1,321, the number last year being 1,336.

Books added to the library during 1911 were as follows:

By Purchase —

American Society of Mechanical Engineers, Volumes 29, 30 and 31.

By Gift—

Annual Report of the Smithsonian Institution for 1909.

Annual Report of the United States National Museum for 1910.

Twenty-seventh Annual Report of the Bureau of American Ethnology for 1905 and 1906.

Twenty-fourth Annual Report of the Interstate Commerce Commission for 1910.

Biennial Report of the State Historical and Natural History Society of Colorado for 1909 and 1910.

Bureau of American Ethnology, Bulletin Number 40, Part 1; also Bulletin Numbers 43, 44, 50 and 51.

Colorado Geological Survey Bulletin, Numbers 1 and 2, presented by Mr. W. F. R. Mills.

Congressional Records—Index to Volume 41, Parts 1–5; also Volume 42, Parts 1, 3, 7 and 8.

Geological Survey of Ohio, Fourth Series, Bulletin Numbers 2, 12 and 13.

Geological Survey of Iowa, Volume 20, and Annual Report for 1909.

Library of Congress Report for 1910.

Mineral Resources for 1909, Parts 1 and 2.

Oklahoma Geological Survey, Bulletin Numbers 2, 5 and 8.

Proceedings of the Iowa Academy of Science for 1910, Volume 17.

Proceedings of the United States National Museum, Volumes 30, 39 and 40.

Records of the Geological Survey of New South Wales, Volume 9, Part 1.

The Mineralogy of Pennsylvania, presented by Mr. John Eyerman.

The Railway Library for 1910.

Wisconsin Geological and Natural History Survey, Bulletin Numbers 21 and 22; also Scientific Series Numbers 6 and 7.

During the past year the Society has been organized into 5 sections, viz.:

1—Technical Chemistry and Metallurgy. Secretary, Mr. H. O. Bosworth.

2—Economic Geology and Mining Engineering. Secretary, Mr. S. A. Ionides.

3—Mechanical and Electrical Engineering. Secretary, Mr. H. S. Sands.

4—Irrigation and Civil Engineering. Secretary, Mr. F. W. Bosco.

5—Pure Science. Secretary, Mr. G. M. Butler.

These Sections have held meetings during the year as follows:

April 8th—Section 1 held its first regular meeting, at which Mr. Lewis B. Skinner presided. He gave the address of the evening on "The Practical Versus the Theoretical Man."

April 21st—Section 2 held its first regular meeting, Mr. S. A. Ionides presiding. Mr. George J. Bancroft read a paper on "The Superficial Appearance and Alteration of Ore Deposits."

September 9th—Section 1 held its second regular meeting, Prof. Herman Fleck acting as chairman. The chair read a paper which had been prepared for this meeting by Mr. F. L. Clerc on "The Utilization of the Zinc Carbonates and Silicates of Leadville, Colorado."

November 18th—Section 1 held its third regular meeting, Mr. Howard C. Parmelee presiding. Dr. Bain read a paper entitled "Methods of Ore Treatment."

November 25th—Section 5 held its first regular meeting, Mr. George E. Collins acting as chairman. The following papers were read: "Recent Developments in Physics," by Prof. L. F. Miller; "Recent Developments in Chemistry," by Dr. J. B. Ekeley, and "Recent Developments in Geology," by Prof. G. M. Butler.

In addition to these, under the auspices of this Society and the State School of Mines, meetings have been held at Idaho Springs, Leadville, Telluride and Ouray, for the purpose of stimulating the mining industry of the state by "Practical Talks" by well known scientific engineers to the miners, mine and mill operators of these towns. These meetings have met with much encouragement from the mining communities and the expectation of good results along the line of more economic management of mines and mills is well warranted.

With the view of broadening the usefulness of this Society and obtaining a fuller measure of benefit of the scientific labor of the community, in the spring of this year, sections were organized. It was considered that these sections would allow for specialization under one organization, which would result in economy in many ways; affording a common meeting place for members, devoting special attention to different branches of scientific investigation, a better fraternizing of these specialists, a more beneficial interchange of ideas and a greater promotion of useful knowledge. These sections are just now getting into working order, and there is every reason to expect the most satisfactory results from the experiment.

On account of threats of increased rental at our former headquarters at 1510 Court Place, it was considered advisable by the Executive Committee to make a change, and after much painstaking labor by the committee appointed for the purpose, the present quarters for our library and meeting rooms were obtained at a rental of $50 per month, which includes light and janitor services. Our museum, which occupies a large floor space, with the kindly consent of the school authorities, was placed in the North Side High School Building, where it is open to the public and will, in addition, serve as a stimulus to the students of the geological classes of that school.

The assistant secretary, Miss Riddle, has rendered good and efficient service, especially to the secretary and treasurer, and for her zeal and ever loyal interest to the welfare of the Society I wish to express, on behalf of all its members, our grateful appreciation.

Dr. William A. Johnston,
Secretary.

REPORT OF THE TREASURER OF THE COLORADO SCIENTIFIC SOCIETY FOR THE YEAR ENDING DECEMBER 16TH, 1911.

418 Boston Building, Denver, Colo., Dec. 16th, 1911.

RECEIPTS.

Balance from statement of 1910	$ 351.11	
Annual dues	1,805.00	
Rent	455.00	
Annual dinner	189.00	
Sale of Proceedings	25.00	
Life memberships	300.00	
Cancelled fire insurance	16.80	
Miscellaneous	10.30	
	$3,152.21	$3,152.21

DISBURSEMENTS.

Rent	$1,100.00	
Printing Proceedings	384.65	
Printing Notices, Ballots and Stationery	233.75	
Lighting	28.95	
Illustrating lectures	41.70	
Postage and Envelopes	133.68	
Fire insurance	86.20	
Salary of assistant secretary	580.00	
Petty cash	73.55	
Periodicals, books and binding	39.00	
Library furnishings and repairs	29.70	
Exchange	.75	
Annual dinner	261.45	
Moving to present quarters	99.10	
Engraving resolutions	6.00	
Miscellaneous	18.50	
	$3,116.98	$3,116.98
Cash on hand		35.23
		$3,152.21

This report shows a total collection of $2,801.10 as against $2,819.00 in 1910, a falling off of $17.90. The total disbursements as shown, were $3,116.98 as against $2,861.53 for 1910, an increase of $255.45.

In analyzing and comparing the expenditures with those of the previous year, you will find the comparison as follows:

DECREASE.

Rent account	$100.00
Printing of Proceedings	80.55
Periodicals, books and binding	26.05
Exchange	1.20
Annual dinner	24.35
Miscellaneous	51.00
	$283.15

INCREASE.

Printing Notices, Ballots, Circulars, etc.	$ 90.05
Lighting	6.20
Postage and envelopes	10.80
Insurance	17.40
Salary of assistant secretary	270.00
Petty cash	18.55
Library repairs and furnishings	12.80
Illustrating lectures	7.70
Moving	99.10
Engraving resolutions	6.00
	$538.60
	$283.15
	$255.45

The chief items of increase fall on cost of printing notices, ballots and stationery, which is due largely to the extra notices and circulars sent out in connection with organizing of the "Sections." The other two important items are the increase in the salary of the assistant secretary, and the cost of moving.

Respectfully submitted,

J. W. RICHARDS,
Treasurer.

Attest:
RICHARD A. PARKER,
Chairman.
FRANK E. SHEPARD.
} *Auditing Committee.*

December 18th, 1911.

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
VOL. X, pp: 123-130.

THE WATER SUPPLY OF COLORADO.

By Charles W. Comstock.

Address of the Retiring President read at the meeting of the Society, December 16, 1911.

There is a well established custom among societies devoted to the advancement of learning, in accordance with which the retiring presiding officer outlines a field wherein his confreres may labor with advantage for the discovery of principles and the accumulation of facts which are needed in the work-a-day world. Thus, while the papers and discussions of the year are contributions toward the solution of problems previously presented, the function of the address at the annual meeting is to state another problem which has been forced to the front amid the changing conditions and which demands our attention.

Conforming to this custom, which I think an admirable one, I have chosen to discuss a subject which has occupied most of my attention for a number of years just past, viz.: "The Water Supply of Colorado."

At the risk of being thought elementary, I must revert to first principles and consider the source of all water, i. e., precipitation from the atmosphere. Rain or snow falls and immediately divides itself among a number of channels. A portion is again evaporated directly from the surface of the ground or from the snow surface. Another portion sinks into the ground, is absorbed by vegetation, and either becomes a part of the plant itself, or is evaporated from its foliage. Still another part finds its way into the ground far enough to be beyond the reach of atmospheric influences and becomes part of the great body of ground water. This third portion itself may be subdivided into two, one becoming part of what is ordinarily known as "ground water," and the other joining the deeper subterranean flow. Finally, a fourth portion runs off the surface of the ground and finds its way into the channels of surface streams.

All of this water, except that absorbed by vegetation, or evaporated, may under proper conditions, become available for use. The subterranean flow supplies artesian wells, of which there are many in Colorado, particularly in the San Luis Valley.

The ground water is in sufficient quantity in some parts of the state to irrigate small tracts of land. The surface flow, although probably only a small fraction of the total precipitation, is relied upon to supply nearly all our demands for domestic, agricultural and industrial purposes.

The division of the water among these various modes of distribution varies widely with the geology, the topography and the climate of the region in which the water flows, as well as with the distribution in time of the precipitation itself.

To cite extreme cases: In the heart of the mountain ranges where there is little soil, where the rocks are bare and the slopes steep, where the altitude is high and the rocks generally of a crystalline character, nearly all the water which falls divides itself into two classes—the first, covered by evaporation, and the last covered by surface run-off. Although temperatures are generally low in such localities, the winds blow almost constantly, frequently with great violence, and the tension of the aqueous vapor in the atmosphere is very low. These two conditions do more to increase evaporation than a high temperature. Vegetation is scant or entirely absent, and, therefore, plays no part in the distribution of the water. There is little or no soil, and the rocks are crystalline and compact. Therefore, the quantity absorbed is relatively insignificant. On the other hand, the slopes are steep and water runs very rapidly to the natural drainage lines of the country.

Per contra, in the open prairie, such as forms the eastern forty per cent. of this state, all the conditions are changed.

The topographical relief is small and the slopes are slight. There is a considerable quantity of vegetation, even on our most barren plains. The soil and sub-soil are deep and often very porous. Even the rocks themselves which underlie the soil, or which outcrop in places, are sedimentary and capable of absorbing large quantities of water. The temperatures are higher, but the winds, as a rule, less constant, and the tension of aqueous vapor generally greater.

We here find one condition which makes for greater evaporation than in the mountains, and two which tend to decrease it. The net result we do not know. The water falling on porous and absorbent soil with gradual slopes does not run off readily, but is absorbed in large quantities. The precipitation itself comes mostly in the form of rain in the warmer portions of the year, whereas in the mountains it is chiefly in the form of snow during the fall and winter months. The vegetation directly absorbs some water and facilitates the evaporation of more.

Thus we find that while in the mountains very little water is absorbed by soil or rocks, on the plains a great deal is disposed of in this way. The quantity evaporated on the plains, as compared with the mountains, is unknown, but is known to be very great, and some is absorbed by vegetation, which is not the case at extremely high altitudes.

The general result is that the run-off from the plains areas to the channels of the natural streams is insignificant, except on those rare occasions of very great precipitation within a short time. This distinction is so marked in what is known as the "arid" or "semi-arid" region that the drainage area of a stream is quite commonly divided into two portions which are known respectively as "contributing" and "non-contributing" areas.

To be enabled to make the best use of the water which falls to our lot, we should know with accuracy the total quantity supplied and the proportion of it which is disposed of in these various ways, under the great variety of conditions which exist in the state.

Three of the elements mentioned are capable of direct measurement, viz.:

Precipitation;
Surface run-off;
Evaporation.

Some work has also been done in attempts to measure the absorption by and percolation through various soils. The results so far, however, have not been such as to warrant any generalizations.

What do we know about precipitation in Colorado?

The Monthly Weather Review, for September, 1911, an official publication of the United States Weather Bureau, gives a list of 156 rainfall stations in this state. Of these, forty-five are in the Platte River drainage basin; thirty-nine in the Arkansas; two in the water-shed of the Cimarron; ten in the Rio Grande basin, and sixty-two in the Colorado River drainage. This totals 158, but two of these stations are counted twice; that at Corona is common to the South Platte and the Colorado drainage, while that at Marshall Pass is common to the Arkansas and the Colorado.

The area of Colorado is 103,948 square miles. We thus have on the average one rainfall station to each 666 square miles, or, say, one to an area of twenty-six miles square. This number might be considered adequate, if the conditions upon which precipitation depends were even approximately uniform throughout the state, which, however, they are not.

By way of comparison, we may note the distributions of these stations in some other parts of the world.

In France the drainage basin of the Seine is 30,327 square miles. The government there maintains 423 precipitation stations, or one to each seventy-two square miles. This is as one for each two townships, as compared with one for each eighteen townships in Colorado.

In the valley of the Rhone there is a precipitation station for each ninety-six square miles; in Switzerland, one for each forty-four square miles.

The entire area of France is less than twice that of Colorado, and if we would maintain precipitation records comparable with those abroad, we must have not less than 1,400 precipitation stations in the state of Colorado. Even the very large number established in the basin of the Seine is deemed insufficient by the engineers charged with the improvement and maintenance of the water-ways in that region, and in the most elaborate and exhaustive report on the flood of January, 1910, prepared by the government engineers and recently issued by authority of the French government, a substantial increase in the number of these stations is proposed.

At the present time, the practice in Colorado among those who are not trained to scientific modes of thought, is to apply the records of the nearest station to whatever area may be under consideration, whether it be large or small, thus unconsciously assuming a uniformity in the distribution of rainfall which the most casual observer knows does not exist.

The question is frequently asked: What is the ratio of run-off to rainfall in this or that drainage area? This question is not answerable for any drainage area in the state of Colorado, for the obvious reason that we do not know how much water falls in any such drainage area.

Meagre and unsatisfactory as our run-off records may be, we know more about the total run-off than we do about the total precipitation.

A second element directly measurable is the run-off, and on this more money has been spent and more work done than on any other, although the records and results are far from satisfactory, partly because some of the work has been poorly done, but chiefly because of lack of continuity.

Not counting stations maintained by private parties, the records of which are not accessible to the public, there are now seventy-three stream gauging stations in Colorado. Of these, eighteen are located in the Platte water shed, twelve in the Arkansas, nine in the Rio Grande, and thirty-four in the drainage area of the Colorado. This last, of course, includes more than one-third of all the state, being the entire area west of the main range except that tributary to the Rio Grande.

This number, small as it is, is five times as great as it was three years ago. It means an average of one stream gauging station for each 1,424 square miles in the state.

In the basin of the Seine the French government maintains 120 stream gauging stations, or one for each 253 square miles.

Concerning this phase of the water supply question, there is little to be said except that there is need for greatly extending it, and strenuous efforts must be made to avoid any break in the continuity of the records.

In the matter of evaporation measurements, almost nothing has been done. Observations have been desultory and scattered. Diligent search has failed to reveal more than one record extending through an entire year. Such observations as have been made have been made without uniformity of method or procedure and are hardly comparable.

So far from being able to know the comparative evaporation in the mountains and on the plains, we are not even in position to state with definiteness the average annual evaporation at any one place in Colorado. This is without doubt a task which should be undertaken by the State Hydrographic Service, but it is a formidable one for several reasons.

Evaporation stations depend for their value upon measurements which must be made with great precision and at frequent intervals. This means the expenditure of a considerable sum for the equipment of each station, and the attendance of a skilled observer. The work cannot be entrusted to such observers as happen to be resident near the station, as is done with a fair degree of satisfaction with stream gauging stations. Our legislature should be asked to provide for an equipment of this kind, and for the proper conduct of these observations.

With accurate knowledge of the total precipitation, the total run-off, and the total evaporation, we can ascertain by difference the quantity of water absorbed by the soil and the vegetation. No method is apparent by which any direct measurement of this quantity can be made.

Valuable work in the direction of the measurement of ground water flow has been done during the past ten years by a number of engineers following in the footsteps of Prof. Charles S. Slichter. It is not unlikely that this may lead sooner or later to some method by which we can determine directly the quantity of water absorbed by the soil and its ultimate disposition. Along this line, I have nothing to suggest.

As said in my opening paragraph, I have only attempted to state some problems demanding solution. The demand is real, and the necessity for definite answers to some of these questions is very great. For these reasons, it has seemed proper and appropriate that they be called to the attention of The Colorado Scientific Society.

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A CRITICAL DISCUSSION OF THE PRINCIPLES OF THE RICHARDS PULSATOR CLASSIFIER

By Lewis B. Skinner.

Read at the Meeting of the Society, March 2, 1912

In attempting to pass judgment on a machine so widely known as the Richards pulsator classifier, I realize that my action will, of itself, be sufficient to lay me open to criticism from some quarters. In order that my attitude will not be misunderstood, I state in the beginning that I have the highest personal and professional regard for the inventor and manufacturers of the machine, and feel that the members of the metallurgical profession, who have to do with ore dressing, are greatly indebted to Dr. Richards for his acknowledged improvements in the art of concentration. Indeed, this feeling is so nearly universal, and Dr. Richards' reputation so fully established, that the task of criticising any of his work is rendered doubly difficult. Some, perhaps, will consider it presumptuous; and I have met those who declined to admit any criticism at all after a perusal of Dr. Richards' books on ore dressing. The only literature which has appeared regarding the classifier has been prepared by those directly concerned in its promotion. There has been no public discussion of its merits from the operator's point of view, due perhaps to a natural reluctance on the part of the operators to criticise apparatus put out by men eminent in the ore dressing profession. It would seem, nevertheless, that a frank discussion of the work of the classifier by those who have actually operated the machine, ought to result only in good and bring to mind points of which the manufacturers may avail themselves. I have had so many inquiries regarding the work of to Richards classifier, that I have decided to save time and avoid misunderstanding by making a public statement which will cover the points as I see them.

It is assumed in the beginning that good classification is an accepted prerequisite to proper ore concentration or separation, and no arguments will be presented in favor of the procedure.

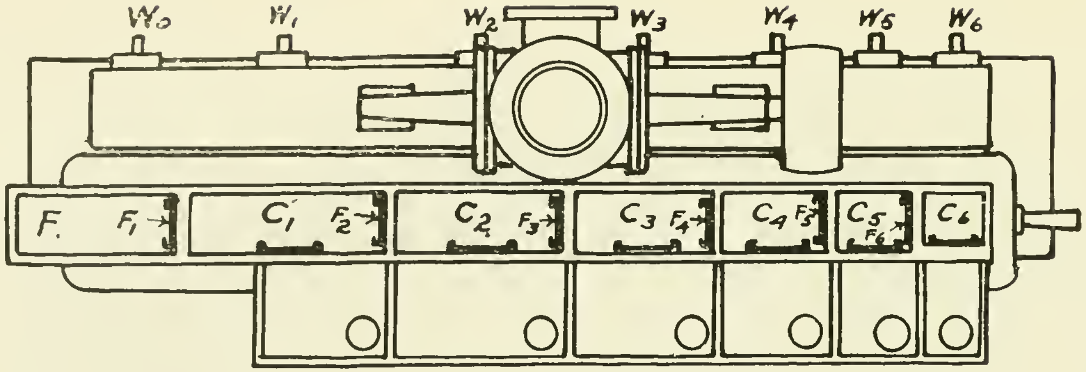
A great deal of time and money has been spent in designing and developing various forms of classifiers. Almost without exception inventors have worked along the lines known as "direct" classification, i.e., a system by which, either with or without the addition of hydraulic water to the pulp, the coarsest particles are separated first and the slime last, with intermediate grades. This system offers the very serious objection that the finer grades become greatly diluted, especially when a hydraulic stream has been used in separating each of the coarser grades. This makes it necessary to thicken the fine grades, and introduces complications in mill design and operation.

Under such a system of direct classification, without the use of hydraulic water, if a pulp is treated containing 30% solids, of which say 10% is slime, we would find about 3% solids in the final, or slime grade. If hydraulic water is used, the condition is even worse, for the original volume of the pulp is diluted with nearly an equal amount of hydraulic water, thus reducing the solids in the slime to 0·3%, most of this hydraulic water being discharged with the original 10% of slimes.

When, therefore, Dr. Richards advocated the use of "indirect" or "inverted" classification, wherein the slime could be eliminated first and the coarse grade last, with corresponding intermediate grades, he took a great step in advance, and it was expected that classification would be simplified and improved. Under this system it was hoped that the slime would not be diluted and the bulk of the hydraulic water would be divided among the coarser grades where it would cause no concern. Finally, the application of the hindered settling principle with the addition of a pulsating action was supposed to add the finishing touch to a practically perfect system of classification.

A brief statement of the principles and operation of the Richards pulsator classifier is here given, reference being made to Fig. 1. Hydraulic water is delivered to the main gate valve "V", at a pressure depending on the size and specific gravity of the ore. It then passes through the pulsating valve "B" and into the manifold "M", which distributes it to the several compartments of the machine. Valves "W" control the supply of hydraulic water to each compartment. An air chamber is provided at "A". The six classifying compartments "C_1" to "C_6" are separated by transverse walls and each wall is provided with an adjustable gate, "F_1" to "F_6". The screen is placed at "S". Ore pulp is introduced at the feed compartment and falls onto the screen, where it is agitated by a rising pulsating current of water. The pulp then passes under gate "F_1" into compartment "C_1" where it is acted on by a pulsating current of water which is intended to lift the lightest, finest particles of the ore out of the mass up to the discharge gate "D_1". The balance of the pulp passes under gate "F_2" to compartment "C_2" where it is supposed to meet a stronger pulsating current of hydraulic water which raises larger and heavier particles to the discharge gate "D_2". This process is repeated in succeeding compartments with still stronger pulsating currents of hydraulic water, resulting in the separation of larger and heavier particles from the pulp. As the discharge gate "D_1" is higher than "D_6", the water in the machine tends to flow towards "D_6", thus washing the ore along the screen.

All slime and fine pulp are supposed to be discharged from compartments "C_1" and "C_2", slightly coarser pulp from "C_3" and so on to "C_6" where the coarsest grains are finally discharged. The pulsating current of hydraulic water is regulated appropriately for each compartment, and presumably each grade of pulp is free from undesirable quantities of undersize and oversize. The bed of ore on the screen is trans-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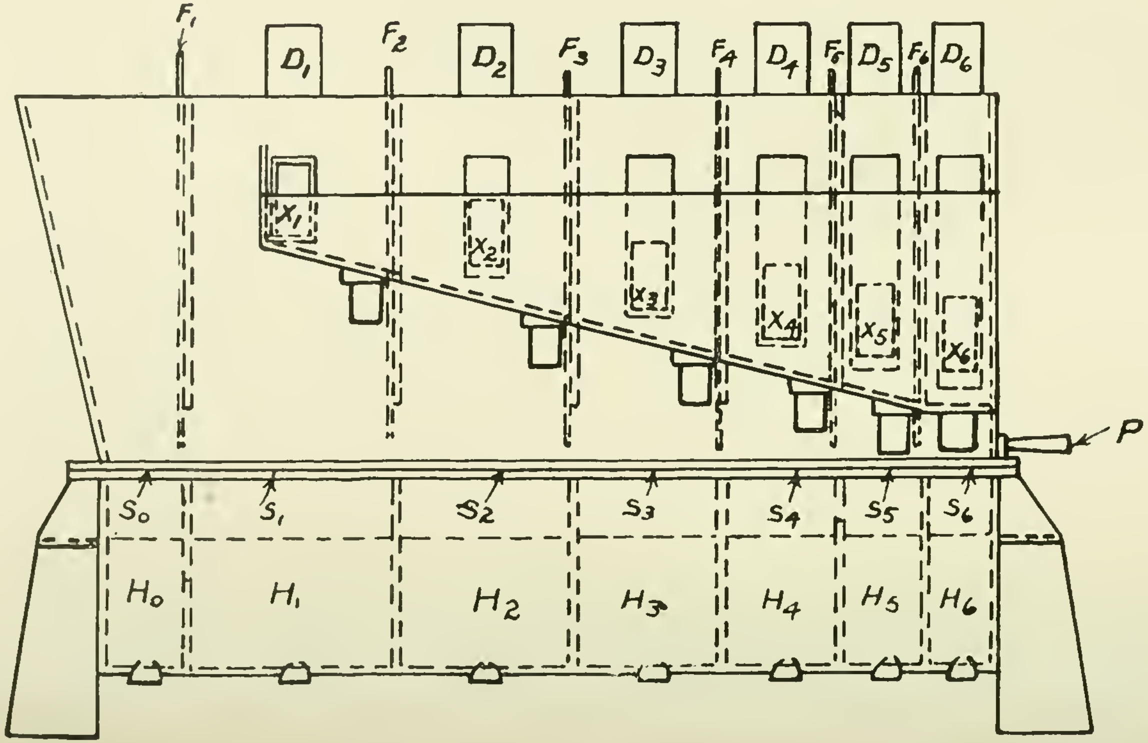
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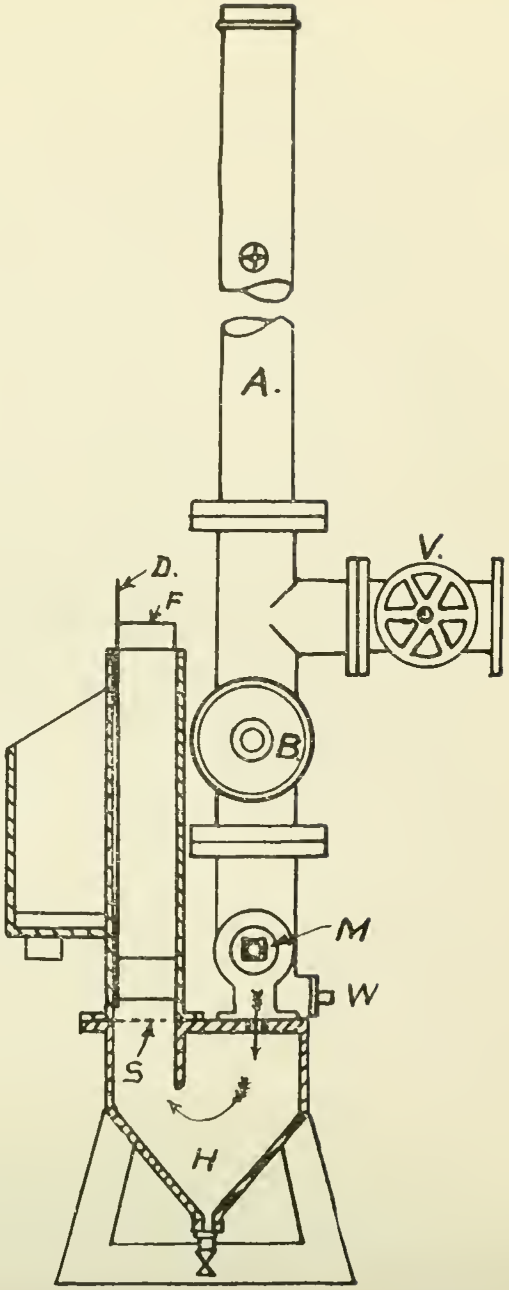
A.
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ported by the pulsating current of hydraulic water and by the difference in head between compartments "C_1" and "C_6".

The principles outlined by the inventor and manufacturers appeal to those who appreciate the theoretical requirements of classification, but the actual performance of the machine has not always measured up to the standard set by its promoters. It is to this apparent discrepency between the ideal and the real, that I have given a great deal of thought, in an effort to discover just wherein the classifier failed to do the ideal work which, in the beginning, it seemed reasonable to expect. It is undoubtedly true that the classifier has done satisfactory work in some instances, according to published reports. It is not difficult to imagine conditions under which the classifier might be acceptable. For example, an ore, containing a small percentage of a single friable mineral in a large percentage of gangue, might break so that the mineral would be much finer than the gangue. Then the gangue might form a sufficiently mobile bed on the screen so that the hydraulic water would transport it in the desired manner without the necessity for very high hydraulic velocity through the screen. Again, consider an ore containing a large percentage of gangue, some pyrite which is nearly barren, and galena which is to be recovered. The pyrite, being of little value, and having a specific gravity between that of galena and silica, would, when the ore is put on a concentrating table, act as an intermediary, even though classification were not good, and protect the galena from contamination with silica. If a small portion of the iron were cut into the galena concentrate, the commercial result would not be greatly affected, and if a part were cut into the gangue, there could be no apparent commercial loss. These and other examples might be imagined, where the niceties of classification could be dispensed with, and the commercial results remain unaffected; but where two valuable minerals must be separated from each other, and both from gangue, the best classification is called for, and this is the demand I had to make upon a machine.

It the first place it seems to me, that one point of weakness in the Richards pulsator classifier lies in the failure to provide adequate, direct and independent means for moving the bed of ore along the horizontal screen from one compartment to the next. No mill designer would expect to use flat launders for the movement of mineral without adding excessive amounts of water to cause transportation. Even then the launders would bank up at times. A jerking motion caused by an eccentric would cause the pulp to progress along the launder, and lesson the trouble, but still a large quantity of water would be necessary.

It seems as though the work of the classifier has been conceived as taking place under fixed, static conditions, instead of the active, changing conditions which really exist. For example, it is easy to imagine that, if a bed of ore pulp were spread on the horizontal screen of the first compartment of the Richards classifier, the slides "F" being pushed down to the surface of the screen, and a pulsating stream of hydraulic water of certain low velocity were allowed to flow through it, a portion of the pulp would be raised according to the velocity of the stream. If then, the balance of the bed were moved intact to the second compartment and there subjected to the action of a pulsating current of greater velocity, a further certain portion of the pulp would be raised, and so on throughout the other compartments. No doubt under such procedure classification would be perfect.

The conditions, however, are not as simple as I have assumed, but far more complex. The supply of new ore is continuous, the slides "F" are raised 2 or 3 inches, and the ore must be transported from the feed compartment to the first and suceeding compartments before being discharged. To accomplish this mere transportation of the ore, an actual test would show that a very large stream of hydraulic water would be required under the feed compartment and under No. 1, with gradually diminishing quantities to No. 6 to cause an overflow of the ore at No. 6. As explained by the manufacturers this transportation of the ore is facilitated by the greater head of water in "C_1" with diminishing heads to compartment "C_6", but the greatest reliance is really placed on the pulsations of the hydraulic water. The conditions, therefore, demand a double duty of the hydraulic water, viz: classification and transportation, with the result that neither is accomplished to the best advantage and the net result is a compromise.

If a certain velocity of current is demanded in "C_6" to *raise* the particles that are buoyant under that velocity, nearly the same velocity is necessary at the feed end of the machine to transport those same particles *to* No. 6 compartment. Since, in the design, the first compartments are larger in screen area, proportionally more water must be passed through the screens of these compartments to raise the bulk of these particles so as to enable the transporting current to move them along the horizontal screen "S".

Now, it is apparent that for perfect classification, it is desired only to differentiate between the actual material we are to separate at any one compartment, and the remaining mass; e.g., the compartment "C_1", material (the finest or slime) from "C_2" to "C_6" material. It must be apparent, also, from logical reasoning that, if any other material is raised off the screen by a high velocity current, a "boiling" or violent agitation of the mass is created, whereby larger sizes will be thrown up into the sorting column. These will overburden the sorting column, and the legitimately rising mass of slime will entangle to a greater or less extent some of these improperly raised coarser products and cause poorly classified material to overflow at "D_1". Of course, this same effect may be expected on down through the several compartments to the last.

To repeat, if a certain velocity is required at the last compartment to raise the coarsest material from the screen, nearly the same velocity must be used at the feed compartment, at No. 1, at No. 2, etc., to enable the transporting current to carry the ore along horizontally without undue friction on the screen cloth.

When a course of reasoning had led me thus far, I conceived the idea of trying to determine the velocity in the sorting columns above the screen, and then to admit just enough hydraulic water to raise the particles desired for this sorting column velocity. As one might readily imagine, the ore immediately "banked up" in the first compartment, because the velocity of the hydraulic water was not sufficiently great at No. 1 screen to raise any material coarser than that desired in No. 1; and since only the right amount of sorting column water was admitted, there was no excess water to transport the rest of the material.

Now, we have already shown that, in addition to the feed-pulp water, an excess of hydraulic water is required to move the bed of ore along the screen from "C_1" to "C_6". It must be conceded that the bulk of this excess hydraulic water will flow parallel with the ore, and that its velocity at every point must be almost as great as in "C_6" where the heaviest particles have to be raised.

It is improbable that more than 10% of the total feed-pulp water, feed-compartment hydraulic water, and "C_1" hydraulic water is discharged with the slime, and we have left 90% which must flow horizontally with the ore. Similar conditions, but with lessening percentages, prevail in all the succeeding compartments except "C_6", where the last of the ore is raised, and where little hydraulic water would be needed on account of the large quantities used in preceding compartments.

The 90% of the water which we have assumed to flow parallel with the ore will carry some slime and fine particles with it into "C_2", etc., where they will be raised and discharged, giving undesirable undersize which should have been discharged before. In other words, when the hydraulic water at any point is forced through the screen and mixed with the ore, it becomes a part of the pulp; and if it has velocity enough to carry *heavy* material to the next compartment, it has velocity enough to carry the *finer* material also. Particularly is this true in the first compartments, where, on account of the original large mass of the ore, more transportation work is required. Of course, in this process some of the transporting-water is continuously becoming sorting-column water, with clear hydraulic water freshly supplied as we pass the ore along. The part of the transportation stream that does successively become sorting-column water in the series "C_1" to "C_6" tends to carry all the ore it is transporting into its compartment, where the lessened velocity in the column must allow that part of the ore which is oversize to drop back against the rising particles which are following, in order that this oversize may again reach the transportation medium. Some of the oversize is battered about by the smaller rising particles, becomes entangled and overflows, as a result of a design whereby work performed by one part of a machine has to be undone in another part. And what about the remainder of the transportation stream which does not rise, but carries forward particles which should have been delivered to the forward compartments?

If we assume, therefore, that 10% of the water admitted up to the point "F_2" overflows at "D_1", and 90% passes to "S_2", this 90% must be of nearly the same screen analysis, and other than poor classification could not be expected.

The actions described as occurring in the feed compartment and in No. 1, persist in the succeeding compartments, and in our case screen analyses have shown that oversize and undersize occur in prohibitive quantities in each grade.

It will be apparent then, that hydraulic water is used in greater volume and at greater velocity than is required for mere *classification* and that this large excess is used alone for *transportation*. This means that one stream of hydraulic water is made to perform two functions of widely different character, with the result that neither is done to the best advantage. And it may be asked in all fairness, is it reasonable to assume that a selective action is going to be exhibited by the hydraulic water, whereby one portion will do the work of classification and another the work of transportation, and that these two kinds of water will contain pulp of widely different composition? Is it not reasonable to assume that a mixed condition is going to exist and that the portion of water that moves parallel with the ore is going to carry a pulp containing a part, at least, of the fine sizes which should have been raised to the discharge gate by the other portion of water?

A second point of weakness which I have noticed is that a uniform bed of ore is not and cannot be maintained on the screen, and that bare spots alternate with sand bars. This condition is due to the fact that the transporting-water, in seeking a path of least resistance, expends its energy of propulsion on the fine upper layers in its horizontal travel and acts only sluggishly on the coarse particles which present greater resistance. Since the coarse particles should properly be those most violently acted upon, as they have to travel farthest to the point of discharge, the means of transportation under the conditions is *not* efficient. Further, owing to the fact that most mill water is not perfectly clean, carrying more or less fine debris, it is impossible to use a very fine screen to support the ore, as such a screen would soon blind. Therefore, screens of a practical mesh are used, thus introducing a difficulty which apparently was overlooked. It was perhaps conceived that the streams of hydraulic water would rise uniformly through the meshes of the screen, dividing into numerous small rising currents of equal velocity. As a matter of fact this probably would occur with a fine throttling screen, such as is used on the deck of a Sutton, Steele & Steele dry concentrating table where a pulsating current of air is similarly used; but with the coarser screens which are found necessary in the classifier, the water seeks paths of least resistance, and having once found them, continues to enlarge them until some parts of the screen are bare and others covered with small sand bars of pulp. The bare spots usually occur near the edges of the screen area of each compartment, under the partition walls, and the irregular beds near the center of the screen. Since these bare spots tend to form and alternate with thick sand bars, the gentle, evenly-rising pulsating current is destroyed, and we have areas on the screen, through which the water is flowing at high velocity while the ore on which it is supposed to be acting lies as an inert mass until a further supply of ore causes a shifting to some other new spot. From time to time, these beds may suddenly break up, flowing into the next compartment, carrying with them particles of pulp which, perhaps, should have been removed in preceding compartments.

It is not unreasonable to expect this result from a current of water of large volume and high velocity rising through a coarse screen. We find an analagous condition in a certain ore roaster in which the inventor planned a large porous hearth, through which air was to be forced for the purpose of slightly agitating the ore and exposing all the particles to the oxidizing action of heated air. While the idea and intention were good, the actual result can be readily imagined when no throttling screen could be used, as on the Sutton, Steele & Steele table. The air currents found paths of least resistance in the ore bed and flowed through these with increasing velocity and volume, forming small "volcanoes" which piled up the ore in some spots and left other portions of the hearth bare. I have observed that similar conditions obtain in the larger compartments of a Richards pulsator classifier, and that, as a consequence, it is practically impossible to maintain a uniform bed of ore on the screen.

In discussing the Richards classifier with other operators, I find three very common criticism which are expressed about as follows: First, the work of the machine does not come up to expectation; second, too much water is required; and third, it is too sensitive, as the machine is no sooner adjusted for one condition, than a slight change of conditions makes a new adjustment necessary.

Although fully realizing the value of constant conditions as to rate of feed and consistency of pulp, I fear that in ordinary mill operation these cannot be maintained with sufficient regularity to meet the demands of the delicate adjustments of a Richards pulsator.

The criticism that frequent adjustment may be necessary can be understood if we consider some mill conditions. Assume that each compartment of the classifier has its hydraulic water adjusted so that a feed of certain screen analysis and consistency is being treated to the best advantage. If, now, the quantity of feed be momentarily *increased*, the quantity of hydraulic water used for transportation also should be immediately increased in order to move the extra quantity of ore along the screen. But the hydraulic water is fixed, and, as a result, the ore tends to bank on the screen, throwing too much feed (and that unclassified) onto the fine tables. On the other hand, assume the classifier adjusted as before. If, now, a momentary *decrease* in ore supply occurs, the quantity of transporting hydraulic water is in excess, i.e., finds little resistance, and moves the ore along the screen too rapidly, with the result that slime and fine particles are moved into compartments beyond those at which they should have been discharged.

Variations in feed can occur even in the normal course of mill operation. Crushed, dry ore discharged into a bin will become classified to a certain extent, depending on the height of fall and the width of bin. In our case this bin must take care of the "go and come" of the ore, so that uniform conditions may obtain at the classifier. This means that it almost fills and empties several times during 24 hours. As the ore is drawn from the bin and sent into the mill system, the screen analysis will vary from hour to hour, and although the variations may not be great, still they will affect the operation of the classifier which has been adjusted to a certain condition. I have adjusted the classifier so that it was doing as good work as it could, and have tried to establish uniform conditions of operation by installing a roller feeder to give a uniform feed, and an overflow tank to give a constant head of water. I have taken the further precaution of posting printed notice of discharge of any employe who tampered with any of the gates, valves, or other parts of the classifier, and have then felt that I might leave the machine and be reasonably certain of uniform work. Imagine my chagrin, upon returning a few hours later to see almost all the feed on the fine tables or vice versa, and that feed improperly classified. I was inclined to blame someone for tampering. After I had continuously experienced this annoyance, I went to the fine storage bin and pushed the partly sorted material down from the sides of the bin, and went below to see what effect would be produced. This upsetting of the bin feed, for I had changed the screen analysis, spoiled the working of the classifier and magnified the variation due to the change.

To repeat and emphasize the point of this argument: If the hydraulic transporting water admitted at the feed end or front compartment of the machine is adjusted for a certain tonnage of ore of a given screen analysis, with all other conditions established, we will have definite overflows at "D_1" to "D_6", with "D_6" having the lowest point of discharge. In the standard design the "D_6" weir is of sufficient size to allow all the hydraulic and feed water to overflow, were no ore present. The tendency to dam up the water and cause overflows at "D_1" to "D_5" is caused by the resistance offered by the ore on the screen "S". This resistance, as a whole, is measured by the tonnage, and the relative resistances between the various compartments is measured by the screen analysis. If, therefore, these are varied only slightly, the transporting water being in so great excess, acts vigorously when changed into sorting-column water where the sorting-column already has an ample amount of water to work properly, and consequently the table-loads vary greatly. This means unclassified material as an average all the time for slight variations at the classifier, the tables taking a longer time to discharge their pulp than these variations of the classifier allow for.

A setting of the valves for the water supply on the original Richards pulsator would, after experiment, settle down in the hands of the manufacturers' expert and in our own adjustment to about the following: feed pulp—⅝″ stream, to keep pulp thin enough to flow properly, W_0—under the feed compartment open full, (this water merely used for transportation in addition to the feed water); W_1—full open; W_2—full open; W_3—⅞″ open; W_4—¾″ open; W_5—½″ open; W_6—

¼″ open. The valves "W" on the machine we used are approximately 1¼″ diameter.

After much experimenting, working with the machine night and day for months in a sincere effort to get good classification out of it, and fully expecting to get the good results claimed for it, I was forced to the conclusion that, under its modus operandi, the best results were impossible. This was not my opinion alone, but also that of others. Mr. R. M. Henderson, at that time mill superintendent at the Western Chemical Mfg. Co., and now manager of the Wellington Mines Co. of Breckenridge, Colo., coincided practically in this opinion. Like myself, Mr. Henderson was disposed to give the machine every chance to prove its worth; and although, when taking charge of the Wellington Mill, he was willing to put a large sum of money, as we had done, into a classifier which would prove satisfactory, he finally evolved one of his own design which he installed. This classifier was described in Metallurgical & Chemical Engineering, November, 1910, page 621. It is shown in side elevation and plan in Figure 2. In this classifier the hydraulic water is without pulsation, the feed flows by gravity down the 45° inclined-bottom of the box and is acted upon by the streams of hydraulic water issuing through horizontal slots in the bottom. The first compartment receives no hydraulic water and gives an overflow of slime. The succeeding compartments receive increasingly stronger currents of hydraulic water and yield increasingly coarser products. The sixth product issues from a vortex sorting column beneath the fifth compartment. The discharge openings of the various compartments are arranged on a descending line parallel with the bottom of the classifier. Although Mr. Henderson says that this device did better work than the Richards pulsator classifier, it was still open to some criticism. The capacity was comparatively low and there was a tendency for the hydraulic water coming through one narrow slot at high velocity in each compartment, to force too much coarse pulp up into the various compartments where it would have to settle again with no hydraulic water or vibrating motion to agitate it before arriving at the next slot. This caused "banking up."

From the suggestion offered by this classifier, I saw that much trouble might be eliminated in the standard Richards pulsator by the use of a sloping instead of a horizontal screen.

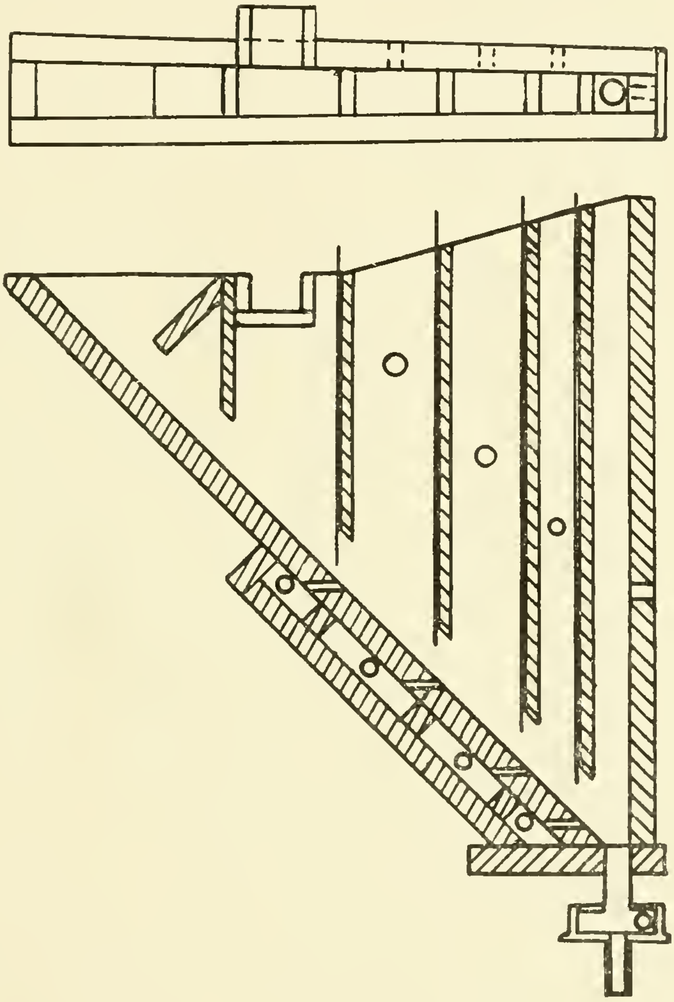


Fig. 2

I built a machine placing the screen at an angle of 22½° and got good results, but came to the conclusion that even less pitch would be better. The inclination of the screen made possible the use of gravity for the transportation of the ore, assisted by the vibration produced by pulsations. The largest particles rolled down the screen fast, the intermediate not as fast, while the lightest remained behind. In this way all particles tended to reach their proper compartments by gravity alone and were more properly acted upon by just the hydraulic current necessary to separate them from the balance of the material. After experimenting with this machine I found classification materially improved, screen analyses and analytical work showing the different grades to contain coarse gangue and fine mineral. Instead of using fixed overflow gates on the different compartments I used adjustable slides with a comparatively small hole in each to regulate the quantity of hydraulic water drawn from each compartment. The slides were so arranged that the head of water in any compartment was about one inch *higher* than in the *preceding* compartment, thus reversing the condition in the standard Richards machine. By this arrangement the difference in head between the water column in the last and the first compartment tended to create a gentle flow of water counter to the ore stream, instead of parallel with it as in the Richards machine, thereby preventing fine material from getting beyond the compartment in which it should have been sorted out. The counter current, of course, would take the path of least resistance which would be at the top of the bed where the finer material would be. I argue that if one wishes to dissolve a soluble gas in water he does not parallel the gas stream and the solvent stream. He has them run counter to each other. Just so, in a classifier, the ore stream should not be parallel to the water current, but should be opposed by it. This is possible in classification only by using gravity to move the ore, with the water flowing in the opposite direction; and in this type of classifier this can be done only by screen inclination.

The wearing out of screens in this design was materially reduced. In the original machine the screen was changed every two weeks or so, until a punched screen was substituted for woven wire, and even then the wear was excessive, as the screen lasted only about three weeks. In the original Richards they cracked at the edges on account of the weight of the ore carried. With the inclined screen, however, it was necessary to make but one change of screens in over a year, and this change was necessary on account of the carelessness of a workman who damaged a screen which had been in service for nine months. The changing of the screen on the original Richards is no easy task on account of rusting bolts and weight of parts.

Early in 1911 I wrote to Dr. Richards regarding the trouble we had had with the original classifier, and I outlined the foregoing changes which seemed to me to embody the following advantages over the original machine: First, the action of gravity moving the ore along the screen; second, the counter-current system, using minimum of hydraulic water to hold back undersize; third, a sorting column under the fifth compartment giving better results than the regular sixth compartment, (this, however, we later found to be necessary, only because a pitch of 22½° was too steep); fourth, variations in feed making little or no difference in the performance of this classifier; fifth, adjusting of the sorting column velocities by the size of discharge holes; and sixth, allowing adjustment of hutch water to just the right amount necessary for the velocity in the column above.

Perhaps on account of a poor presentation of the reasoning attempted in this paper, my suggestions were unproductive of actual results.

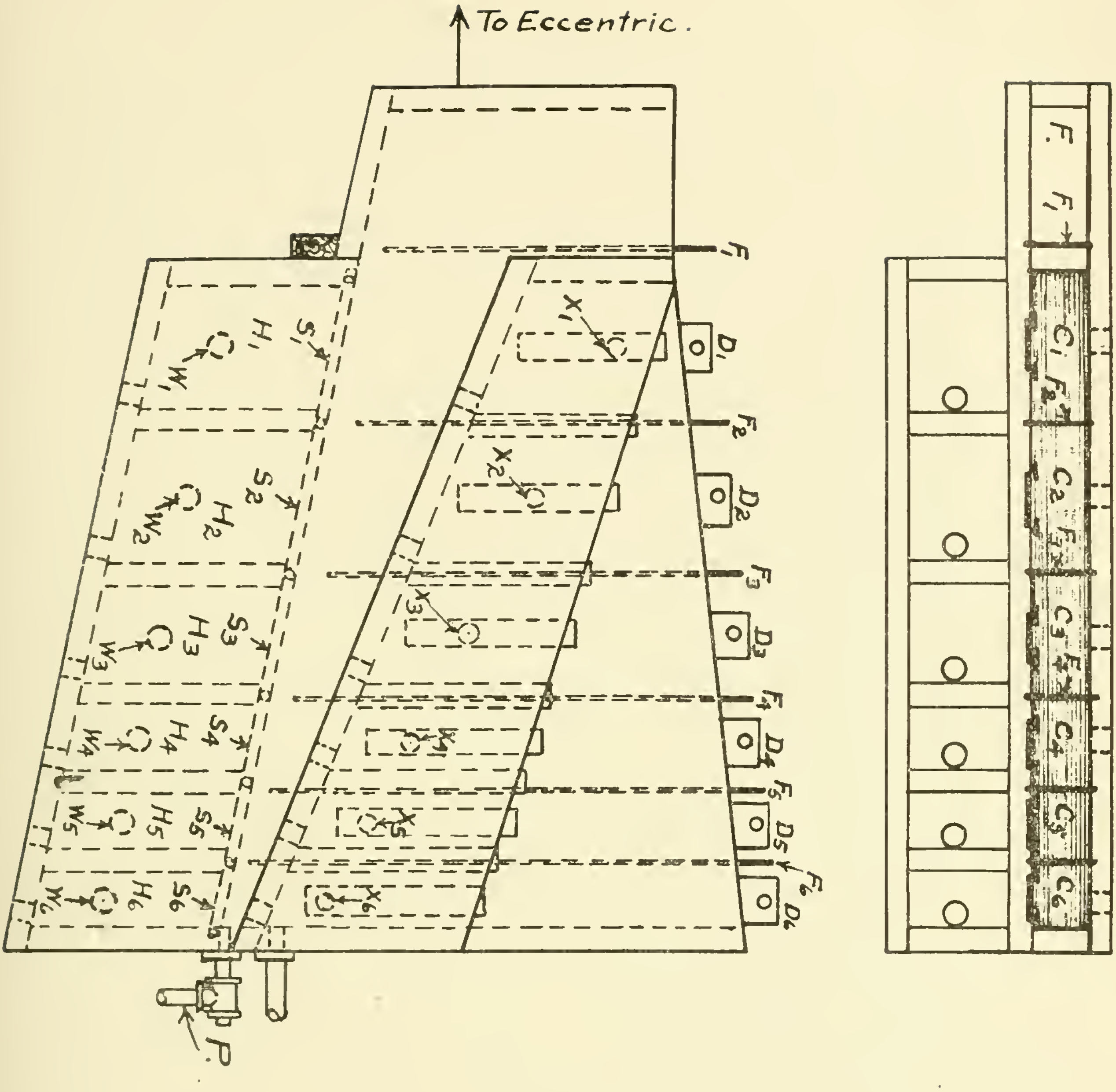
However, a number of changes have been made in the classifier during the past year, viz., placing a rib at each partition "F" projecting about 1″ above the screen level, *so as to maintain a bed;* abandonment of valves "W" and slides "F"; but I cannot see wherein they have improved the original design as far as meeting my objections is concerned.

Further experience with the altered classifier just described convinced me that still greater improvement was possible, provided the different forces acting in the classifier could be brought under separate means of control, and each made to do its work independently of the others. Some form of the vibratory or pulsating motion is certainly desirable, but in order to be most efficient, it should act as a separate force and not as a quality of the hydraulic water. The idea of the shaking classifier then suggested itself. In this, an eccentric motion imparted to the classifier box would act as a disentangling and transporting force, while non-pulsating hydraulic water would furnish the necessary sorting-column water. I tried to design a machine so as to shake the screen independently of the classifier box, but figured that stuffing boxes would be too difficult to maintain, and in addition, found an advantage in shaking the material in the sorting columns.

In the Richards pulsator classifier, the pulsating force is applied practically vertically in an attempt to keep the ore bed free and open, and to disentangle the pulp in the sorting column. It occurred to me that a shaking motion applied horizontally would more suitably maintain the ore in condition to be acted upon, by aiding materially in transportation, and that disentanglement in the sorting column would be more pronounced by a sidewise impulse than by a vertical.

The result of this study and experiment is the evolution of a classifier of the following description. See Fig. 3. A box adapted to be shaken longitudinally is divided into six vertical compartments "C_1" to "C_6" with an inclined screen "S" placed between the compartments and the corresponding hutches "H". The inclination of the screen is not more than 15°. Hydraulic water without pulsation is introduced into the hutches, the velocity being regulated suitably for each compartment. The screen, so called, is in reality a miniature grizzly made of spring-brass bars 1/40″ thick, spaced 1/40″ apart. The space blocks are so placed as to come directly beneath the compartment partitions and thus avoid the formation of bare spots at those points. As mentioned before, the discharge openings in each compartment are arranged so that the head of water in any compartment is about one inch higher than in the preceding one.

In operation, the ore pulp is fed in the usual manner, and falls onto the inclined screening surface "S". The shaking motion tends to act strongly upon the heavy particles and less


To Eccentric.
F1
F2
F3
F4
F5
F6
D1
D2
D3
D4
D5
D6
X1
X2
X3
X4
X5
X6
S1
S2
S3
S4
S5
S6
H1
H2
H3
H4
H5
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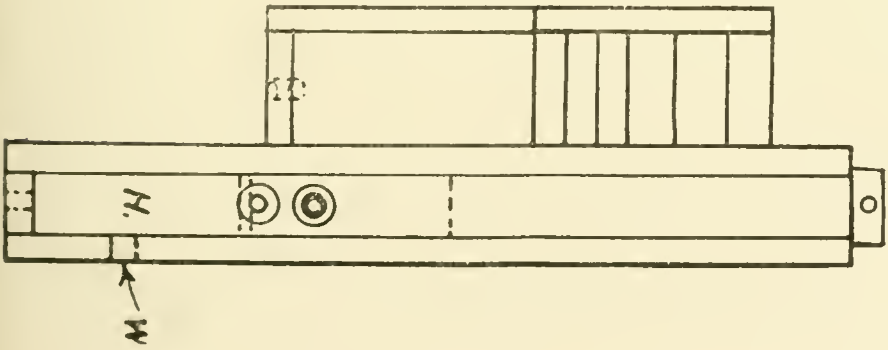
C6


H.
W

strongly upon the intermediate, so moving them at the desired velocities along the inclined screen, while the fine tends to remain behind. By using an inclination of only 8° I tried to stratify the material as nearly as possible with the idea of picking off the lighter supernatant layers; but I found that the more nearly the machine approached the Richards design of horizontal screen the poorer the classification became; and that trying to use little hydraulic water in No. 1, more in No. 2 compartment and so on caused "banking up," variable distribution to tables and constant changes. When I arrived at an inclination beyond 15° I found that, for our ores, the coarse material rolled down the screen too fast, with the shaking type, and that too high differences of head in the sorting columns would have to be maintained, i. e., the head in, say No. 6 compartment would be nearly three inches higher than in No. 5. This caused a too violent cross-current underneath the opening "F", so tending to disturb the quiet conditions sought. Since the difference between the greatest inclination necessary and the least is only some five or six degrees, this adjustment may be provided for by raising or lowering one end of a standard design.

Since building the shaking classifier, I have found that it would have been better not to design the machine with the screen at one continuous inclination, but to put the screen on a curve, or with a slight angular change in each compartment as shown in figures 4 and 5. No water at all is needed under the feed compartment or under No. 1, as the overflow from No. 1 is the fine material that would not in any case quickly settle to the bottom of the feed compartment, but is held in suspension in the water fed in with the pulp and overflows at "D_1". At "C_1" the screen inclination should be pitched at a sufficiently steep angle to allow of the easy flow of the pulp which does settle. In falling through the column of water in the feed compartment and by being acted upon by this feed water rising, all the sorting effect that can be hoped for is had on the material (slime) which rises in "C_1". Slime pulp may be considered almost as a fluid for all practical purposes

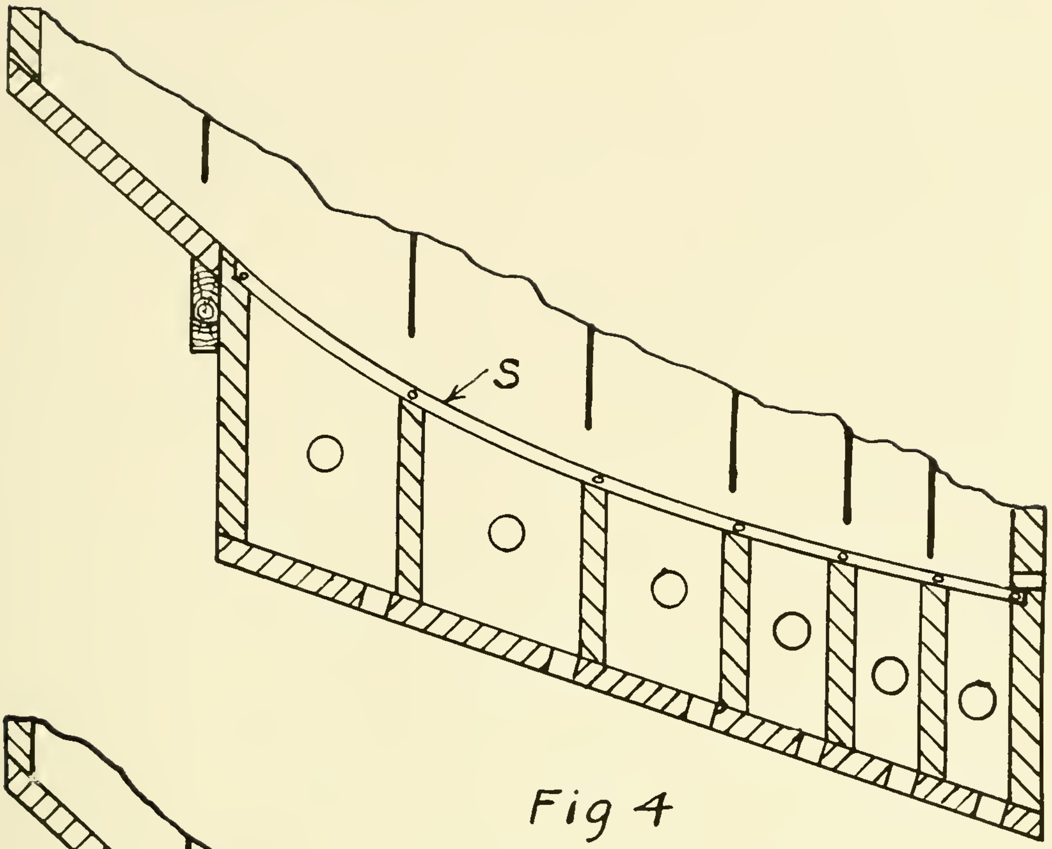


Fig 4

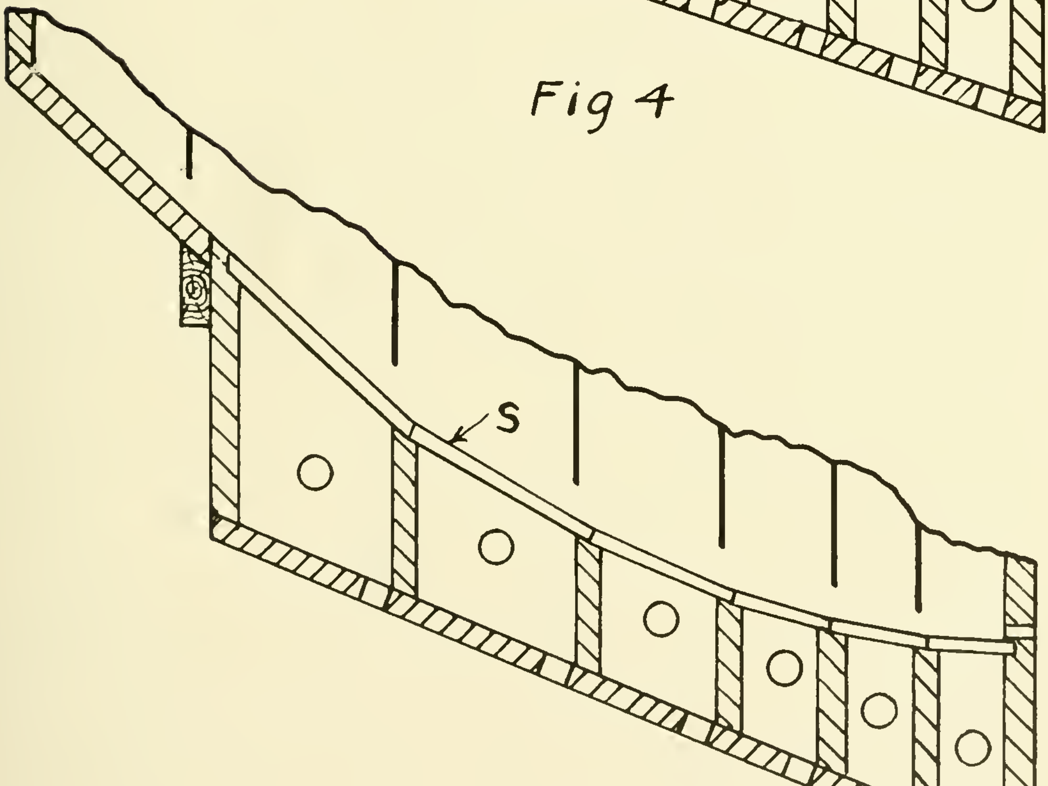


Fig. 5.

in ore dressing. At the No. 2 compartment the screen should have a slightly lesser pitch from the horizontal, as it is desired to retain coarser particles than those composing the slime in No. 1. At “C_3” the angle should be less than “C_2”, as it is apparent that there is also a decreasing amount of ore as we pass along. The distance on the screen is less and we wish to retain certain sizes continually growing larger which can remain behind at decreasing inclinations. In other words, the angle in each compartment should be steep enough to allow gravity to carry from it that material not desired in that compartment, without any need for water transportation; and at the same time it should not be so steep as to tend to cause those to roll away which should properly rise.

For classification I have found that the principle applied in magnetic work, that of selecting material from a layer “one particle thick,” is much to be desired over that in which bedding or stratification is used, with a lifting off of supernatant layers. In the latter case there is too much tendency to entanglement. Further, with the “one particle thick” idea the hydraulic water may issue through all parts of the screen area in a given compartment at equal velocity, as there is not that resistance due to banks of ore, compelling the water to come through small parts of the screen area at a higher velocity than that in the sorting column above, and so blowing up oversize into this sorting column. It has actually worked out with the machine now installed that there is some accumulation on the screen in compartments 1 and 2, showing the necessity for increased inclination here. As a consequence, we have to use a little too much hydraulic water; but further on, the ore passes along so that there is no appreciable accumulation. I tried using a little more hydraulic water under Nos. 1 and 2, to prevent any apparent accumulation, but found, as I expected, that more oversize material would be discharged on account of the disturbance. Now, if the angle were greater, even less hydraulic water could be used in the finer size compartments than now, and better work obtained.

I have been made aware that in the case of several millmen it has been imagined that the velocity of the hydraulic water through the screen at any compartment will determine the velocity in the sorting column directly above it. That this cannot be so, may be shown by looking at Figure 1. Suppose that, with all the hutches (H) filled with water, a stream is turned on in "H_0"; the lowest place of discharge would be "X_6" in "D_6". In other words, the whole sorting velocity would be in compartment 6 and the chances are that all the ore but the slime would settle on the screen between "S_0" and "S_6", were no hydraulic water supplied for "H_1" to "H_6". So, in any supporting screen classifier, only enough hydraulic water should be introduced all the way along to keep the material loosened from the screen. If too much is introduced at any one point it causes a violent disturbance or "boiling"; but, in any case, it would not affect the velocity of the water in the sorting column above it. That is determined by the size of the weir with the head back of it, and this head is influenced by the damming effect of the amount of ore on the screen in the path of the water current. With holes in the slides "D" of definite small area almost the same water will be discharged from each compartment with no feed as when the ore is acted upon; and the sorting columns, therefore, will have the same velocities for all feeds and therefore sort the same sizes.

In regulating the inclined-screen shaking classifier, there is no damming of ore or "banking," and a proper regulation would be as follows: First, admit the pulp of as thick a consistency as possible; regulate the discharge slides so that the holes are as high as possible on No. 1, and as near the screen as possible on No. 6 compartment. These discharge holes, on a 6-compartment machine will run from ⅝″ diameter on "D_6" to about 1¼″ on "D_1" with intermediate holes in proportion, the machine handling 50 to 100 tons per day. In passing it might be well, however to call attention to the fact that the larger holes "X" at the first compartments will not actually discharge as much water as will the smaller at the back end owing to the difference in head in the sorting columns.

The hydraulic water should be so regulated that no appreciable amount of ore can be felt on the screen. If this occurs more hydraulic water must be used at the compartment where felt. If the screen is so bare that the small particles cannot be felt rolling down to the last compartment, some hydraulic water should be turned off. This should result in a proper division of pulp to the tables or other separating devices. Also, there should be a gradually reduced opening of the hydraulic water valves from “W_6” to “W_1”, “W_1” opened little if any. Whether this has been properly performed may be checked by the result that there should be about an inch increase of head each from “C_1” to ”C_6”. If oversize shows on any one table the gate “F” between its compartment at the classifier and the next below should be raised to allow this oversize to pass.

If, on account of the average screen analysis, the arrangement should not show definite progression in elevation of the discharge openings “X”, the holes “X” should be made larger or smaller to allow of a larger or smaller amount of sorting-column water to discharge. I have found it almost imperative on our ores, if a vortex sorting column is not used at the last, to have a seventh classification discharge from the screen level at “P”. At the end of the classifier above the discharge opening “P”, we have a ½″ pipe connected to the water supply. This is for use of the workmen who may open it to throw on a little more water when the supply of ore is a little coarse and to shut off when there is a considerable amount of fine. This pipe valve, when opened and closed, possibly once in several days, saves the other adjustments from disturbance when once satisfactory. I have run for months without finding any need of change, as the sorting column velocities have the same effect on a given size, and the effect of gravity rolling a particle down the screen to its proper compartment is practically the same whether the tonnage is large or small.

Of course, the pulp delivered to the tables will be more or less diluted in proportion to the tonnage fed, with the classifier water remaining uniform, but all the tables receive their proportionate amounts, and do not vary back and forth between the fine and coarse tables as in the original Richards classifier where the tonnage and other variables determine the overflow in the different compartments.

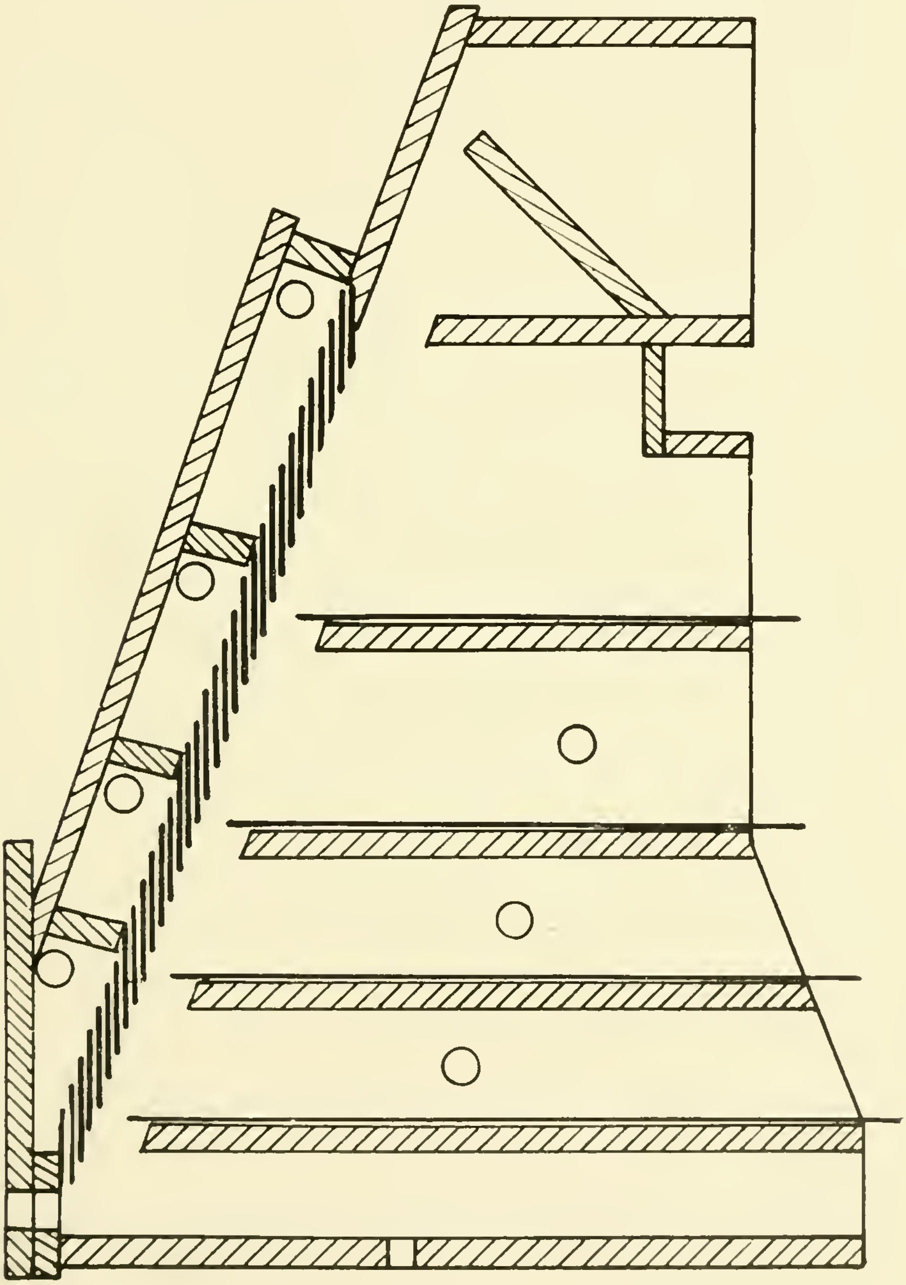


Fig. 6.

To sum up: The machine itself is automatic or "fool proof," which, in any machine, is greatly to be desired. There is not the necessity for continual adjusting by an expert to take care of variation of operation. Fine-haired adjustments may be made, and these only tampered with when the valves clog or changes are necessary from wear.

After having this design in mind for some time, I suggested its use to Mr. R. M. Henderson, and he built and installed two machines working on the inclined-screen and shaking principle. He informs me that the first installed did excellent work, and that in his experience he had never seen as good classification. The second classifier which he built at the Wellington Mill, was not so successful, due to his alterations in design of the perforated screening surface which tended to mix and disturb the ore. See Fig. 6. The falling from step to step as shown in this screen surface is objectionable, as will be evidenced by a study of the foregoing arguments.

In this discussion it has been my aim to avoid destructive criticism by offering something constructive, and I regret that it is not advisable from a business point of view, on account of operating a custom mill, to present screen analyses, analytical work, curve sheets, etc., in corroboration. We have them. If, however, the matter has not been logically presented, no amount of prejudiced data would make the argument plainer. It has been my endeavor for some time, to find fallacies in the improved scheme which has been presented, so that it could be perfected as far as possible before making it the basis of a paper. Discussion of any of the ideas advanced will be gladly welcomed, as I am interested in seeing progress made in the art of ore separation and dislike to see any one take a backward step in an effort to overcome present difficulties. There is no necessity, therefore, to revert to old forms, such as launder-pocket classifiers, which operate on the "direct" classifying principle, and introduce the difficulties arising from the dilution of fine pulps. If the present criticism will aid in securing better design in classifiers and save mineral which in many quarters is now lost because of their imperfections, my object will have been achieved.

DISCUSSION.

Mr. Frank E. Shepard.—The Western Chemical Manufacturing Co., Mr. L. B. Skinner, General Superintendent, purchased a three-inch, six-compartment Richards pulsator classifier on December 24th, 1909, for classifying pulp at the rate of 50 to 60 tons in 24 hours.

Their ore is crushed dry, then roasted to render the iron contents magnetic. The magnetic plant removes the iron, leaving a roasted lead-zinc pulp of high specific gravity, with an unusually small percentage of gangue. The following is an approximate screen analysis of the feed to the classifier:

80 per cent. will pass through 20 mesh screen
40 per cent. will pass through 40 mesh screen
20 per cent. will pass through 80 mesh screen
15 per cent. will pass through 100 mesh screen
5 per cent. will pass through 200 mesh screen

With reference to the Richards pulsator classifier from an operator's point of view, valuable data will be found in an article by Mr. George W. Brown, mill superintendent of El Tiro Copper Company, published in Mines and Minerals, January, 1909.

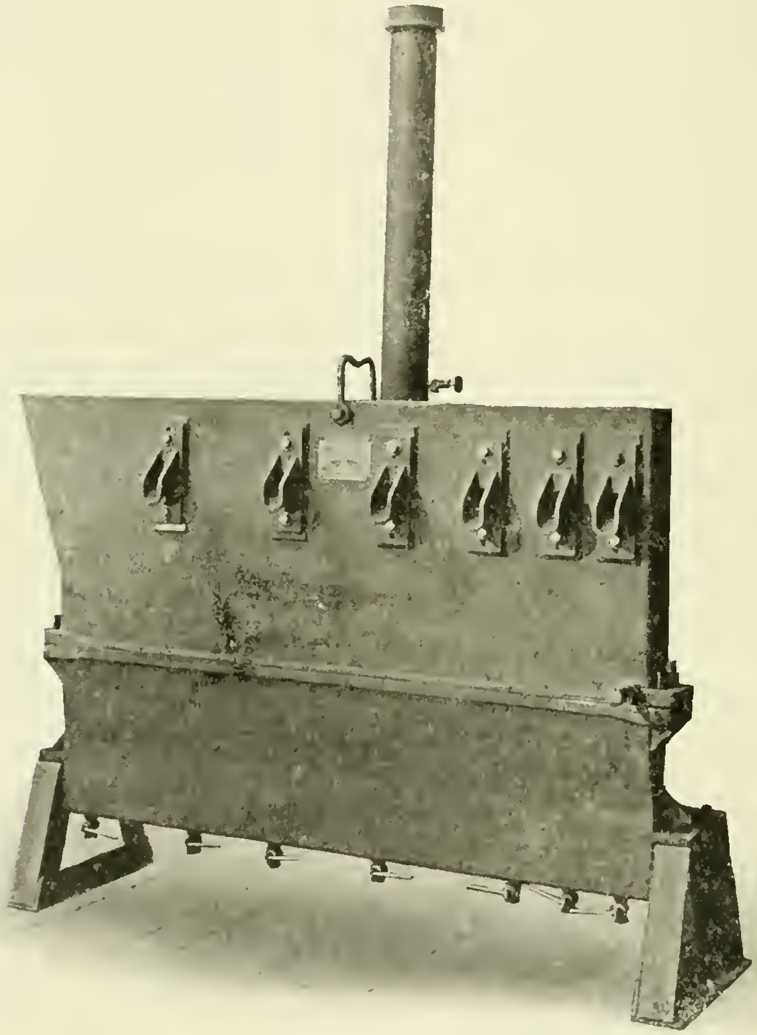
The Richards pulsator classifier referred to by Mr. Skinner is similar to the early design described in a paper read before The Colorado Scientific Society entitled "The Richards Pulsator Jig and Classifier," under date of November, 1908.

Dr. Robert H. Richards, the inventor, gives reports of tests and progress in his work on "Ore Dressing" as well as in The Mineral Industry.

Mr. Skinner criticises the amount of hydraulic water necessary to move this lead-zinc pulp along the horizontal screen and proposes an inclined screen for the purpose of reducing the amount of water.

This proposed inclined screen will prevent the formation of high grade hutch products so generally obtained in the pulsator classifier with horizontal screen.

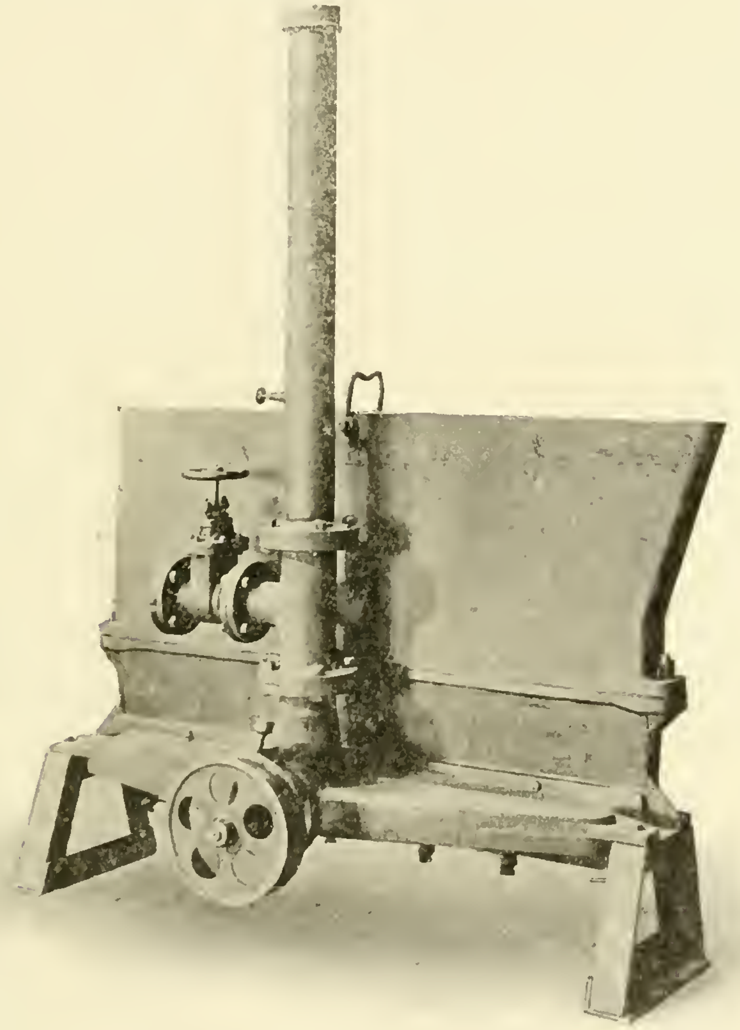
The inclined screen will require experiments on each grade of ore to determine the proper angle of inclination and will call for sensitive adjustments of feed and hydraulic water, as acknowledged by Mr. Skinner in his letter of December 10th, 1910, to Dr. Richards, saying: "Of course, I understand that this inclined screen design will be very sensitive and that any change in feed would change the working to a material extent * *." In connection with this inclined



Front View, Richards Pulsator Classifier.

screen Mr. Skinner uses a continuous current of hydraulic water instead of the pulsating current. The continuous hydraulic current repeatedly has been proved to cause injurious currents, tending to mix fine with coarse pulps.

The longitudinal shaking motion will produce wave movements which interfere with good classification.



Back View, Richards Pulsator Classifier.

Fig. 3 shows six water valves delivering hydraulic water to the hutches; one additional water supply to create a counter water current and still another water supply to produce a sorting action in the coarse pulp compartment.

This makes eight water valves to adjust.

The latest type of Richards pulsator classifier has but one water valve to adjust.

The longitudinal shaking motion requires eight flexible hose connections which are apt to leak and require frequent renewals.

Mr. Skinner follows the general design of the Richards pulsator classifier of the inverted type in discharging the slime pulp from the first compartment; he uses the gates between the compartments, also the discharge gates, all of which require to be adjusted.

The design of classifier with inclined screen shown in Fig. 3, including gates and water valves, has twenty parts to adjust. The latest design of the Richards pulsator classifier has but seven parts to adjust.

Figs. 4 and 5 show the necessity for different angles of inclination for the screens, which must be determined for every different ore pulp. This makes it impossible to have a standard machine, and a new classifier must be designed for every new ore pulp—and then after experiments to determine the proper angles for the screen.

A cast iron classifier treating 75 tons of pulp in 24 hours will weigh 1,250 pounds. To shake this mass at a speed to keep pulp in complete agitation will require much more power than for a pulsator valve.

Then there are necessary braces to resist vibration, and the supporting details with shaking motion require more space and a careful alignment.

A self-contained and stationary machine is more consistent with good mill practice.

Fig. 3 of the proposed inclined screen type shows gates "F" between the classifier compartments. These gates must retard the progress of pulp down the inclined screen, else why use these gates?

Then the depth of the pulp on the inclined screen at the lower end of the compartment is very much thicker than the stream entering the compartment. It is obvious that the unifrom thickness of pulp, "one grain deep," as suggested by Mr.

Skinner, does not exist. Hydraulic water passing up through a deep layer of pulp at the lower end of the compartment, and at the same time through a very thin layer of pulp at the upper end of the compartment must surely produce a very uneven water current.

The absence of hydraulic water in the feed compartment throws on the slime compartment the additional work of breaking up and separating the masses of ore pulp such as result from dry crushing and subsequent roasting.

The pulp is fed in this particular plant by means of a screw conveyor five feet long, and water is added to the pulp while passing along the conveyor. With this arrangement lumps are likely to enter the feed hopper, and need an intermittent water current to thoroughly disintegrate the pulp.

The pulp treated by Mr. Skinner is very much heavier than the usual grade of pulps treated in hydraulic classifiers and accounts for the larger amount of water found to be necessary. This particular pulp will require more than the usual amount of water under any system of hydraulic classification.

If in the Richards pulsator classifier with horizontal screen the gates between the compartments had been removed entirely and the discharge gates adjusted to a line more nearly horizontal, less water would have been required and good results obtained in classification.

The present design of classifier has but one water valve to adjust and one set of discharge gates requiring but one preliminary adjustment for each type of ore.

Under average practical mill conditions no difficulty is found in maintaining an even bed of ore on the horizontal screen; the classified pulps are delivered of proper consistency to the tables, and reasonable variations of feed and water supply do not require any changes in adjustment.

The manufacturer aims to provide apparatus as simple as possible to meet the widely varying conditions of ore treatment.

Mr. Skinner's design would introduce the necessity of greater power, a greater number of parts to adjust, and fully as much intelligence in the practical operation.

His earnest and persistent work in developing a special system of classification for a very difficult ore pulp is to be commended, but it is to be regretted that an equal persistence and enthusiasm could not have been devoted to the operation of the standard type of Richards pulsator classifier with horizontal screen, in which case equally good results would have been accomplished.

Mr. F. C. Bowman.—Mr. Skinner's chief criticism seems to be on the flat screen used in the Richards classifier, and the large amount of transportation-water which he states is necessary to move the ore along the screen, diluting the pulp and carrying with it material which should have been left in preceding compartments.

A very good analogy in the transportation of material along a horizontal screen surface and under similar conditions, is found in the ordinary jig—the only difference being that, in the case of the jig, transportation is not assisted by a difference in static head between the different compartments, but is retarded by the divisions between compartments. And yet this machine has been in use for years without encountering the objections mentioned by Mr. Skinner, viz: excessive screen wear; forming of impervious bars on portions of the screen and violent agitation at other points; and failure to provide direct and independent means for moving the material along the screen from one compartment to the next.

It might be well at this point to call attention also to the very small head necessary in the case of the jig to cause the bed to move from all portions of the compartment to the side discharge for concentrates. This will enable one to form an idea of what a small difference in static head is necessary between two adjoining classifier compartments to cause material to flow from one compartment to the next.

In order to overcome these supposed troubles Mr. Skinner proposes an inclined-screen, shaking classifier, the chief object of the inclined screen being to convey the ore one particle deep along the screen by gravity, and thus materially reduce the amount of hydraulic water needed. Mr. Skinner states that he has found this machine "fool proof" and capable of automatically adjusting itself to 100 per cent. variations in feed. While the machine may be fool proof, although I have yet to see such a machine in use in a mill, it is hard to imagine a machine capable of adjusting itself to such variations and automatically maintaining the material one particle deep on the screen, which Mr. Skinner states is necessary for good classification.

Some three years ago I had occasion to install one of the 3-inch 6-compartment inverted type Richards classifier, of probably about the same model as the machine used by Mr. Skinner. The screen furnished with the classifier was a Tyler double-crimped brass, 20 mesh No. 24 wire.

The classifier was working on a 20-mesh pulp previously thickened by a 4-foot standard thickening cone tank, the ratio of water to ore by volume in the classifier feed being about 2 or 3 to 1. The concentration ratio of the ore was about 5 : 1, the concentrate being mostly pyrite, although there was a small amount of galena concentrate. The hydraulic water was delivered to the classifier under a variable head of 27 to 35 feet. The ore handled by the classifier was 60 tons per 24 hours.

No one about the mill, including myself, had ever seen the machine in operation, so there was some little difficulty, natural to any new machine, in getting started; but it was found that after the machine was once adjusted to the average running conditions, it became almost automatic in accommodating itself to variations of feed, due to hanging up stamps, etc.

The thickening tank gave occasional trouble from choking, due to large feed escaping from holes in the battery screens at times. A careful record kept of the amount of time spent on the tank and classifier, (most of which was spent on the tank), showed only a total of 35 hours for one month, equivalent, at 30 days, to 70 minutes per day of 24 hours, or 23 1-3 minutes per 8-hour shift, which showed that the machine needed very little attention.

When clear hydraulic water was used, the last three compartments, delivering the coarse products, gave material free from slime, and the water with these products was clear. There was no thickening of pulp between the classifier and tables as the consistency of the pulp just as it came from the classifier gave very good results on the tables.

The wear on the classifier screen was hardly noticeable.

Each day the hutch produced about 500 pounds of clean iron concentrate, carrying several ounces of gold per ton, which was the highest grade concentrate produced in the mill.

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY
VOL. X. pp: 165–184.

COMMERCIALLY IMPORTANT ARTIFICIAL GEMS.

By G. Montague Butler.

Read at the Meeting of the Society, April 6, 1912

The Distinction Between Imitation and Artificial Gems.

In order to prevent any misconceptions, I desire, first, to emphasize the fact that imitation gems are not artificial gems in the sense that I here use the term.

Nearly all precious stones, with the possible exception of the opal, have been successfully imitated, so far as appearance is concerned, in glass or enamel. These form the so-called pastes or strass, and they differ in physical and optical properties from the stones they simulate. Even their colors and degrees of transparency are apt to be far from permanent. While certainly artificial, they cannot be called artificial gems for the very good reason that they are not gems. This statement applies with equal force to the ever popular doublets and triplets, which are at best merely thin slices of natural gems combined with colored glass. Neither are we concerned with natural substitutes for more valuable gems, such as zircon, phenacite, white sapphires, white topaz, rock crystal, and other substitutes for diamond.

The artificial gems of which I shall speak are practically identical with the natural stones in all physical and optical characteristics, and differ therefrom, often, solely in origin. They are just as much "real" gems as artificial ice is real ice, and are not to be confounded with Pliny's "glass gems from the rings of the multitude." They are designated as reconstructed, synthetic, or scientific stones, and these terms are regarded as synonyms in the gem trade although not strictly synonymous as I shall show later.

ARTIFICIAL DIAMONDS.

There are at least ten distinctly different processes by which real diamonds of gem quality may be manufactured. In no case, however, are the crystals produced as much as a millimeter in diameter, and the product is usually much smaller than this. While melee diamonds less than a millimeter in diameter are used in jewelry, the artificial stones of this size cost so much more than the small natural ones that artificial diamonds are of no commercial importance.

The question is often asked: "Since so much success has been attained in the manufacture of various synthetic products, is it not merely a matter of time before commercially important synthetic diamonds will appear on the market?" One need not hesitate to answer no to this query, for it is a fact that we are now apparently just as far from a satisfactory solution of the problem as were the workers of fifty years ago. And this is true in spite of the further fact that more time and energy have been expended upon efforts to manufacture diamonds than have been employed in attempts to reproduce any other gem—probably all other gems.

We seem unable to apply the enormous pressures and the extremely gradual, uniform rates of cooling that are available in the laboratory of nature, and which appear to be a prerequisite to the formation of diamond crystals of considerable size.

It is true that reconstructed and scientific diamonds are offered for sale by unscrupulous or ignorant jewelers; but these names are absolutely fallacious and are intended to deceive the purchaser as to the true nature of the articles, which are without exception substitutes or imitations.

While on this topic, it may be interesting to recall the little known fact that there is at least one other substance which could be used with entire satisfaction in place of diamonds for all purposes to which this mineral is applied. I refer to boron. This is as hard or harder than the diamond, and approaches very closely, or equals it, in refractivity and dispersion; but it has so far proven impossible to form crystals large enough for gem purposes.

GEM CARBORUNDUM.

In 1910, F. J. Tone, of the Carborundum Company of Niagara Falls, N. Y., patented a process for making transparent, colorless or tinted carborundum suitable for gem purposes. It is claimed that the product has an even higher coefficient of refraction than the diamond, and, if this is true, it should make a splendid gem, as it is, of course, between ruby or sapphire and diamond in hardness. None of this substance has appeared on the market, and a recent letter from Mr. Tone says that commercially "the matter was never carried through to any successful issue." This appears to be a field well worthy of investigation.

ARTIFICIAL OPAL.

About a year ago I noted a paragraph in a jewelers' magazine to the effect that William Rose, a lawyer of Independence, Mo., had succeeded, after a life-time of effort, in making opals of a quality suitable for use as gems. I corresponded with this gentleman, and wish to read the following self-explanatory quotation from a recent letter: "I do not expect to imitate the natural stones, nor do I wish to do so, as I do not desire to make anything that could be used to perpetrate a fraud. * * I do not want to imitate, but to make a new substance for the arts, which can be worked up into several beautiful forms none of which can be imitated in glass."

Mr. Rose has kindly given me three samples of his product, and a brief description of these may be of interest. They look like slightly milky, colorless, transparent opal, are optically isotropic, and have such a low thermal conductivity as to indicate that they are amorphous; but the hardness is nearly seven. Sharp corners of the so-called opal scratch quartz with difficulty, while quartz scratches it with comparative ease. The specific gravity is 2·20. The material utterly lacks the exquisitely beautiful play of colors from the interior which makes the precious opal the most beautiful and fascinating of all gems. One of the specimens contains tiny square flakes of gold-leaf, another, similar lamellæ of some translucent, pink substance, while in the third the inclusions are some milky-white, anisotropic mineral, possibly muscovite mica. The manufacturer claims that the substance is pure, amorphous, anhydrous silica. He refuses to give a hint as to how it is made.

Although the product possesses scientific interest, it does not form very promising gem material, nor can it be called commercially important. Press notices indicated that it did deserve to be so-called, however, so I do not feel that the account given is out of place. I am as desirous of dislodging misconceptions as of disseminating reliable information.

MISCELLANEOUS STONES PRODUCED ARTIFICIALLY BUT OF NO COMMERCIAL IMPORTANCE.

Within the last hundred years a large number of gems have been successfully reproduced in the laboratory. Among the more important are the following: Peridot, diopside pyroxene, rock crystal and other varieties of quartz, precious topaz, phenacite, beryl (aquamarine, emerald), zircon (hyacinth, jacinth, jargon), and chrysoberyl (cymophane or cat's-eye). In every case, however, the artificial product is either much more expensive than the natural mineral, or else the crystals produced are too small to cut into gems.

It is impossible to predict what will yet be accomplished in the commercial fabrication of these and other gems. In the case of the emerald, long and painstaking experimentation has yielded only negative results and future success seems improbable; but most of the other gems mentioned are of such comparatively small value that their reproduction would bring the manufacturer an inadequate financial reward. They have, therefore, received little attention from experimenters. This is true, for instance, of the zircon, a most splendid stone possessing all the qualifications of a gem to an unusual degree. Among the ancients, it was a great favorite, but the fickle public has now forgotten it and magnificent natural stones are sold with difficulty at even a fraction of their true value. There is, naturally, slight reason to attempt to produce such a stone in the laboratory.

ARTIFICIAL TURQUOIS.

I have seen statements to the effect that real turquois has been made on a commercial scale by a secret process, supposed to involve the application of great pressure upon small quantities of powdered phosphate of aluminum containing a trace of copper, this being the material of which turquois is composed. As the artificial stones are said to fuse to a black glass, whereas turquois is infusible, it appears extremely improbable that the fabrication is real turquois or even has the composition suggested.

Only small stones of this type have been placed on the market, and these are sometimes stained with limonite to still further simulate the natural gem. Dr. Max Bauer claims that, when placed in water, this material darkens in color, and he also says that the surface shows many minute cracks when examined with a lens.

ARTIFICIAL RUBY.

We now leave the artificial gems of no, or doubtful, economic value and attack a subject of the greatest scientific and commercial interest, i.e., the manufacture of the various corundum gems—oriental ruby, sapphire, etc.—whose base is oxide of aluminum.

In order to lead logically up to the subject, allow me to quote from a lecture delivered by Dr. G. F. Herbert Smith of the British Museum.

> "As long ago as 1837, Gaudin, by fusing together in a closed crucible equal parts of alum and sulphate of potassium, obtained small hexagonal plates, about 1 mm. in thickness and 3 mm. in width. Ebelman, some

years later, in 1851, derived similar plates from a fusion of alumina and borax, and made a step forward in coloring them by the previous addition of small quantities of metallic oxides. Sainte-Claire Deville and Caron obtained good results a little later, in 1858, by fusing aluminum fluoride with boric acid, and, by adding varying quantities of chromim fluoride, produced not only ruby, but also sapphire and the green variety, the so-called oriental emerald. Gaudin had in the meantime been devoting himself to the manufacture of imitation gem stones, and in a paper published in 1869 he stated that he obtained vitreous globules by fusing alumina powder in the oxy-hydrogen flame. In 1877, Fremy and Feil published an account of their interesting and instructive researches. They fused together equal weights of alumina and minium (lead oxide) in a siliceous earthen vessel. The aluminate of lead which was at first formed immediately attacked the silica of the crucible and formed a lead silicate; the alumina thus set free crystallized out in beautiful hexagonal plates, which were colored red or blue according to whether the oxide of chromium or of cobalt was previously added to the mixture. A portion of a crucible lined with ruby flakes is exhibited in the mineral gallery of the Natural History Museum.

"Twenty-four years ago, in 1885, red stones of unknown origin and mysterious production made their appearance on the market from the direction of Geneva. Having the physical properties of genuine rubies, they were accepted as, and realized the prices of, natural stones. We now know that probably they were formed by the melting together of fragments of natural ruby in the oxy-hydrogen flame. The details of the process of manufacture, no doubt, varied slightly, but in the main it was as follows: Two, or perhaps three, oxy-hydrogen jets played horizontally onto the top of an infusible pedestal, which was kept in slow rotation about a vertical spindle. The ruby fragments were dropped, one by one, by means of platinum forceps, onto the top of the pedestal, where they melted into a single mass. A little potassium bichromate was added in order to give the proper color. Owing to the inequalities of growth, the cracks due to rapid cooling, and the inclusion of air-bubbles, often so numerous as to cause a cloudy appearance, and above all, the unnatural, brick-like color, these reconstructed stones, as they have been properly termed, were far from satisfactory."

Some of the corundum gems now on the market are made by this or a similar process, and are the only ones truly deserving of the title reconstructed. Since, however, this appellation had already become firmly established before the better, cheaper gems appeared, it is quite customary to speak of all artificial corundum gems by this name.

In addition to the methods described by Dr. Smith, still another process was tried before Verneuil solved the problem satisfactorily. This involved the fusion in a porous clay crucible of a mixture of alumina, carbonate of calcium, barium fluoride, and potassium chromate. The mass had to be kept at a temperature of 1500°C. for about a week, and the resulting rubies weighed less than half a carat, so the price was about that of natural stones.

In 1903, A. Verneuil, Professor of Applied Ceramics in the Conservatory of Arts and Trades, Paris, France, a pupil of Fremy, published a paper on the artificial production of the ruby by fusion, in which he described the method by which nearly all the best gems are now made. Briefly, the process is as follows: Pure powdered ammonium alum is calcined until all the water, sulphur, and ammonia are driven off, and the pure powdered alumina—oxide of aluminum—thus formed is then mixed with about 2% of oxide of chromium. This mixture is then melted in a specially designed furnace with an oxy-hydrogen or other flame, and solid red corundum—ruby—is formed. Ammonium alum is used as a raw material merely because it is more readily obtained than any other compound.

Fig. 1 is a diagrammatic section of the apparatus used. It is not drawn to scale, and I have made no attempt to have it exactly correct in detail.

The powdered alumina and oxide of chromium are placed in a receptacle with a sieve bottom and this is introduced within the oxygen chamber. Small quantities of this mixture are sifted out of the box at each blow of the cam-actuated tapping hammer. This powder falls with the oxygen until the fusion chamber is reached. There the union of the oxygen with the hydrogen or coal-gas produces an intense heat, and, when the powder encounters this high temperature, the mixture melts and a tiny drop of molten ruby falls upon the support below.

At first, the powder is released very slowly and a low gas pressure is used. So a small, cylindrical stem of ruby called a pin-head first attaches itself to the pedestal. As this pin-head gets larger, the pedestal is gradually lowered, the gas

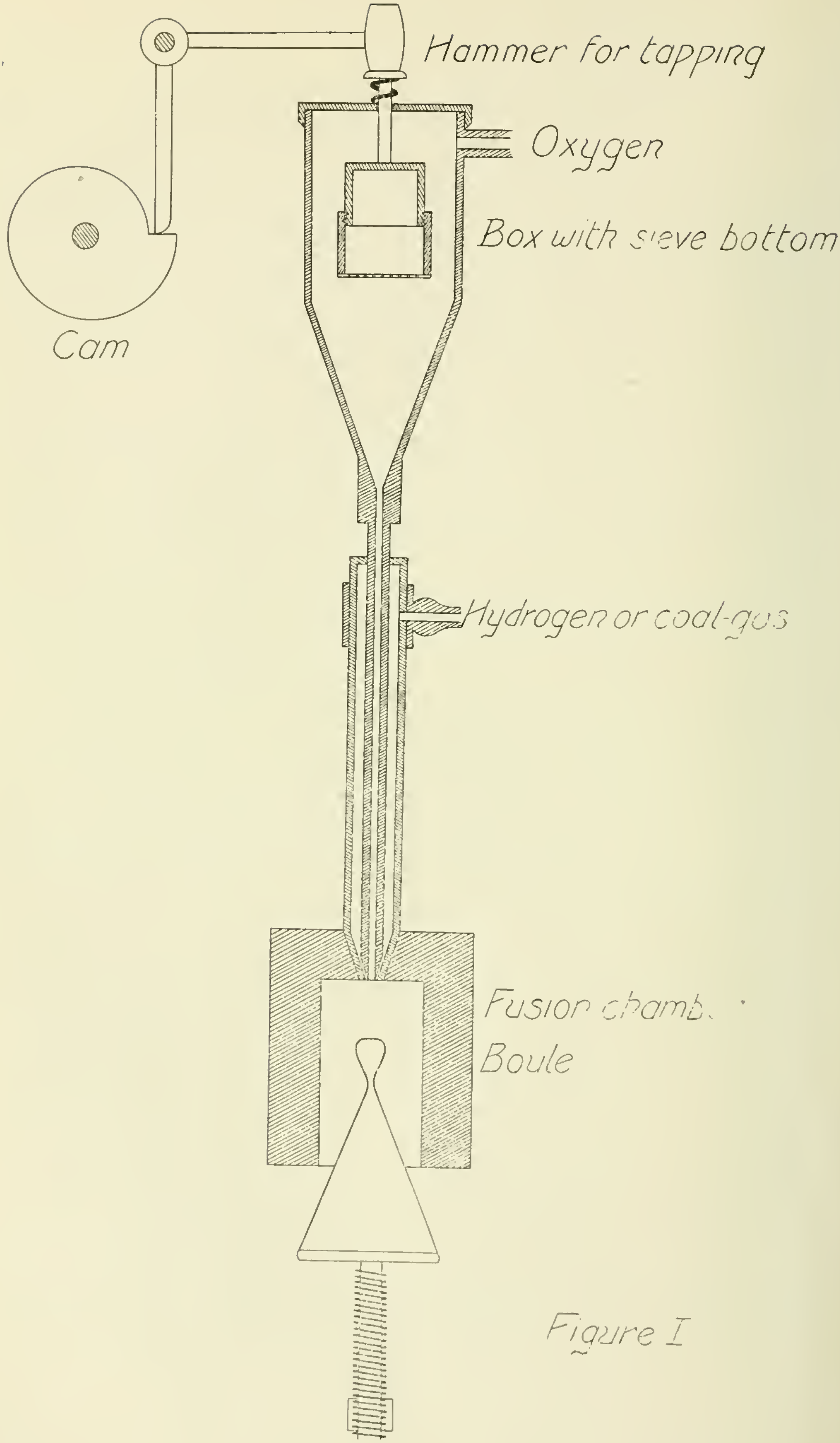

Hammer for tapping
Oxygen
Box with sieve bottom
Cam
Hydrogen or coal-gas
Fusion chamb
Boule

Figure I

pressure is increased, and the powder is released more rapidly, causing a pear-shaped mass of ruby to accumulate. This is called a boule. It is necessary to start the operation slowly and at a comparatively low temperature in order to avoid melting the pedestal.

Coal-gas has now been substituted for the costly hydrogen used at first, and the process is so simple that it is said that one man can look after a dozen of the machines if the cams are on a common shaft. It is reported that about an hour is required to form a boule large enough to cut into a ten carat gem. There is an upper limit to the size of the boule obtainable in this way. A cut stone weighing twelve to fifteen carats is about as large as it has been possible to produce.

Gems formed in this way are usually termed synthetic, and this is a perfectly satisfactory name, but means little to the general public. By some makers, powdered ruby is used instead of calcined ammonium alum, and the resulting gems are correctly termed reconstructed. Scientific can be applied to both, but some dealers have inexcusably used it when referring to glass or other imitations. While these may be scientific, they are not scientific gems.

Nature of the Boules.

Contrary to what one would naturally expect, the boules formed in the manner just outlined are not glass—amorphous—even though their form and general appearance very strongly suggest this. Each of the boules is a nearly anhedral or faceless crystal with the vertical or C axis parallel to the axis of revolution of the boule. The upper surface has an etched appearance; and, if this portion be examined with a powerful lens, many tiny crystal faces in parallel position are seen. These crystals are plainly rhombohedrons, and the angle between adjacent faces proves to be the same as that of the unit rhombohedron of corundum—ruby.

The boule has the composition, hardness, crystallization, specific gravity, coefficients of refraction and double refraction, dichroism, transparency, lustre, and color of the ruby. It is in fact, genuine ruby made by man rather than by nature, and, like many other substances including ice and indigo, man's production is of better grade than the average of the natural material.

If the stem of a boule be broken off, the boule itself will usually split lengthwise. This is an advantage rather than otherwise since it leaves the material in good shape for cutting.

Artificial Sapphire.

With the attainment of success in the manufacture of the ruby came a desire to produce its sister stone, the sapphire. Now it was known that some natural sapphire has exactly the same composition as the ruby, the color being due to the presence of some oxide of chromium just as in the ruby. Why in some cases a red and in others a blue stone should form is uncertain, but it is probably the result of the presence of different combinations of chromium, various oxides of chromium, and alumina, formed under different conditions.

After some experimentation, it was found that gems formed in the manner just described were invariably red or pink, so an attempt was made to use other coloring agents. Cobalt oxide was found to be unsatisfactory since the blue color was never uniformly distributed through the stone. Ferrous oxide in a reducing atmosphere was also used, but the result was a very dark blue which appeared quite black at night. This duplicated certain Australian sapphires, but did not possess enough beauty to be valuable. In another experiment, lime was added with the oxide of cobalt, and a beautiful, uniformly blue boule was obtained, but it proved to me amorphous —merely a blue, cobalt glass.

Finally, early in 1910, a small proportion of titanic acid and ferric oxide was added to the alumina, and the result was the scientific sapphire. This stone is produced exclusively in the laboratory of the Hellerite Company in Paris, under the direction of Prof. Verneuil and I. H. Levin, an American graduate of Columbia. It has been patented under the name of the "hope sapphire," and is handled in this country by the

American branch of the firm, L. Heller and Son, New York City.

Scientific rubies are made by many concerns, but this company is the only one producing genuine sapphire.

Before leaving the discussion of the sapphire, it should be stated that some natural sapphires are colored by titanium and iron.

ARTIFICIAL BLUE SPINEL.

In 1907, it was announced, prematurely as it proved, that the problem of the production of sapphires had been solved; and I immediately procured one of the stones. It proved to be only eight in hardness, was singly refracting, had a specific gravity of 3·62 (corundum is about 4·), showed cubo-octahedral crystallization on the upper surface, and turned purple in artificial light. These characters identified it as blue spinel, and it was no surprise to learn that it was made by adding magnesia and cobalt oxide to the ammonium-alum, thus forming an artificial cobalt spinel of a different tint from any found in nature.

Practically all of the so-called scientific or reconstructed sapphires on the market, with the exception of the hope sapphire, are these blue spinels.

ARTIFICIAL CORUNDUM OF VARIOUS TINTS.

Previous to the formation of the true sapphire, it was found possible to fabricate other tints of corundum gems by the use of other coloring agents.

Beautiful pink sapphires, resembling the color of the burned topaz, were made by reducing the proportion of chrome-alum used.

White sapphires resulted when no coloring matter was employed.

Oxide of nickel produced straw-, or canary-, yellow stones which the Hellerite people patented under the name "golden sapphire." Different proportions of the oxide of nickel gave a gem which was bluish green in natural, and reddish in artificial light. This was named "scientific alexandrite," an unfortunate choice since it was not alexandrite—an oxide of beryllium and aluminum. Similar poorly chosen names are scientific hyacinth, almandine, and pink tourmaline for salmon, purplish red, and light pink stones, in which various coloring agents are used.

Oriental emerald (green)—not the ordinary emerald of the jewelers— and oriental amethyst (purplish)—not the amethyst with which we are all so familiar—have not yet appeared on the market.

Distinctions Between Artificial and Natural Corundum Gems.

1. All tints of the scientific stones are very apt to contain one or more spherical air or gas bubbles a millimeter or less in diameter. They are often very small but so many are sometimes present as to give the stone a cloudy appearance.

Natural stones may contain cavities, but these are invariably bounded by flat faces instead of curved surfaces or else are very irregular in shape.

Most of the better scientific stones contain no bubbles visible to the naked eye and few visible with a lens, while some of the best grades show no bubbles whatever.

2. Any tint of the scientific stones may show a series of tiny, parallel cracks at some point. They usually run from the surface towards the interior for a millimeter, more or less, but are sometimes present in the interior of a stone. They are not at all common, and a good grade of material is much more apt to lack, than to show, them.

These cracks doubtless correspond to the parting cracks produced in natural corundum by oscillatory twinning parallel to the faces of the unit rhombohedron. Although this parting is very common on the more opaque or massive varieties of corundum, it is excessively rare on crystals of gem quality.

3. As far as the ruby is concerned, the most distinctive feature of the artificial stone is the usual presence of very narrow, *curved* lines or striæ of light and dark tints of color, similar to those shown in Fig 2. These are only visible when the gem is viewed from a certain direction with a good lens,

and are produced by the existence of varying proportions of chromic oxide in the successive, concentric layers of corundum, of which the boule is formed. If one layer has more chromic oxide than the next, it will naturally possess a darker color; and two successive layers rarely have exactly the same tint.

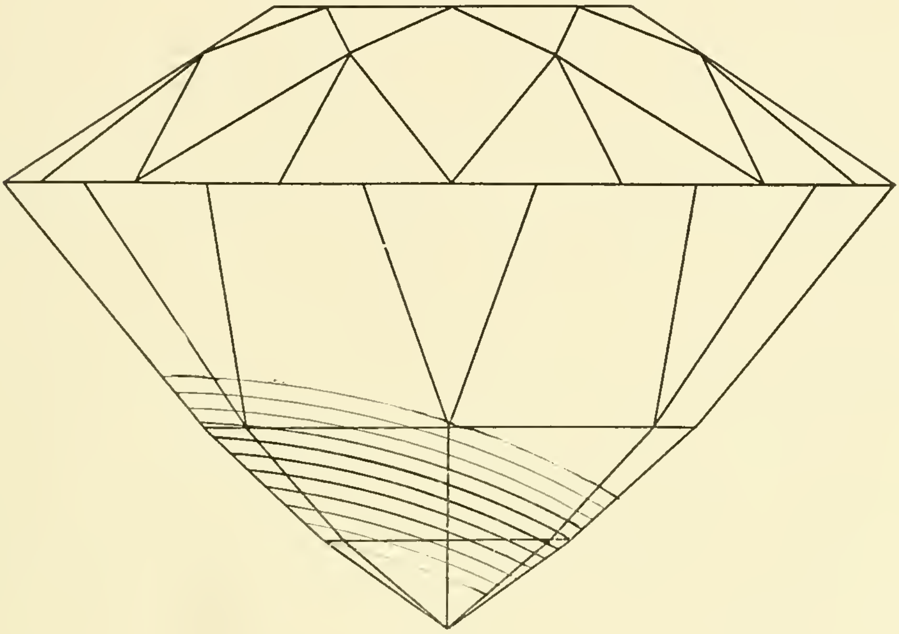


Figure 2.

These lines or bands of color are quite inconspicuous; in fact, it is often very difficult for one untrained in their detection to see them at all. A good lens is required, and it is frequently necessary to view the stone in various lights and to turn it slowly until examined from all possible angles before one's search is rewarded. Great care must be exercised not to confuse these striæ with scratches on the facets of the gem due to insufficient polishing. The surface scratches change direction on adjacent facets, while the colored lines pass under adjacent facets without change of direction.

If the gem is so cut that the striæ are only visible from the side, they may be completely hidden by the mounting.

Natural stones may show similar irregularities of color, but the bands are usually wider than those in the scientific gems. More important still, *the natural bands are never* *curved.* In the natural gem, the bands may appear as a series of parallel, straight lines or they may be bent at angles of 60° or 120°. Such bands result from the deposition of differently tinted layers upon the surface of a growing hexagonal crystal.

Of the hundreds of scientific rubies that I have had the privilege of examining, I have seen only two or three that utterly lacked the striæ described. In manufacturing these, the ingredients were doubtless more finely powdered and intimately mixed. Possibly, also, the boule was kept more fluid for a longer interval than usual. At any rate, the manufacturers seem unable steadily to produce rubies that are perfectly homogeneous so far as the color is concerned.

4. The artificial sapphire may show curved lines of color similar to those described above, but they are not as common as in the case of the ruby, and are, as a usual thing, so much broader as to be plainly visible to the naked eye.

Blue sapphire, "synthetic almandine," and ruby are the only scientific corundum gems that ever show such bands or lines of color.

5. The ruby, blue sapphire, pink sapphire and synthetic almandine, hyacinth, and alexandrite are often very poorly cut and polished. For round stones, a brilliant-cut crown (top) and a step-cut pavilion (bottom) are usually used, and the proportions are apt to be so poor that the gem appears relatively dark and lifeless in the center with brilliant reflections around the edge. This is the result of the employment of very cheap foreign labor in cutting the gems, something that is not done in the case of the very expensive natural stones.

6. The golden and white sapphires cut by the Hellerite Company are well proportioned and brilliant-cut like a diamond, but they are poorly polished in some cases, and the culet (the tiny face in the middle of the back) is a square instead of the usual octagon.

7. The artificial corundum gems never show the "silky" flaws which are fairly common in natural ruby and sapphire.

In fact, all the scientific corundum gems average better, clearer, cleaner, than the natural ones.

8. The color of the ruby may be an unnatural brick-red, and it is usually a bit darker than the "pigeon-blood" tint. Natural rubies are, however, seldom of that tint.

POSSIBILITY OF CONFUSING THE ARTIFICIAL AND THE NATURAL CORUNDUM GEMS.

Some claim that "an experienced gem expert will recognize the natural ruby by its peculiar, characteristic, soft, silky brilliance, which is lacking in all artificial rubies," while others state that experts can always recognize the artificial product by the color alone.

Such claims as these are sheer folly, resulting largely from ignorance. The lustre of a gem depends entirely upon its optical properties, and in these particulars the artificial and natural corundum gems are *absolutely identical.* It is true that the color of the scientific ruby is often poor but so is that of the natural stone. Long handling of gems and minerals has given me a delicate color sense, yet I have seen scores of scientific stones of precisely the same tint as nature's product.

While it is certainly true that a scientific ruby is very unapt totally to lack striæ, bubbles, cracks, and still be of good color, I contend that it is quite possible to make gems like this and that such stones can not be distinguished from natural gems. I have, in fact, seen one or two in this class.

Since the scientific sapphires are less apt to show bands of color, they are more frequently perfect than are rubies, and are then utterly impossible to distinguish from the best natural stones. This may be true either of light or dark tints, but is more apt to be the case with the former.

Finally, a considerable proportion of the white, pink, and golden sapphires are so clean that their artificial nature is completely masked. The other tints are so rarely found in nature that one is safe in assuming all such stones to be artificial.

STATUS OF, AND MARKET FOR, THE ARTIFICIAL CORUNDUM GEMS

Some of the biggest and most exclusive retail jewelers refuse to handle the scientific stones. They hope by so doing to deceive their customers into believing that they are mere imitations, unworthy of consideration, and thus to continue to find a market for the very profitable natural gems. They claim that the introduction of the scientific stones has had little or no effect upon the price of the natural gems; and this is true to some extent, since the price has been kept up to a figure out of all proportion to the demand, which has fallen off very badly and will continue to decrease as the scientific gems are better understood and appreciated.

In spite of everything, the scientific ruby has become very popular, and the other tints are fast gaining in favor. Enormous quantities are being sold and the supply is hardly equal to the demand. The white sapphire is a favorite substitute for the diamond. It possesses the qualification of great hardness and cold brilliance, but its dispersion is so low that it shows none of the prismatic colors that make a diamond so beautiful. Anyone familiar with gems can distinguish the two as far as he can see them.

The increasing vogue of the colored scientific stones is as it should be if gems are worn because of their permanent intrinsic beauty and ornamental value. Those who use gems in order to make an ostentatious display of their wealth will have to fall back upon stones other than the corundum gems, since it is becoming increasingly true that a ruby or sapphire is considered artificial until proved otherwise.

The following are the prices of these gems as quoted on large lots at wholesale. The variations noted are due to differences in quality, size and perfection of cutting and polishing.

Ruby—$0.50 to $1.25 per carat. (Least expensive because of competition).

Sapphire—$1.00 to $3.00 per carat. (Most expensive because in great demand and patented).

Pink, golden, and white sapphire—$0.75 to $1.50 per carat.

"Synthetic alexandrite"—$1.50 to $2.50 per carat.

"Synthetic almandine" or "pink tourmaline"—$1.00 to $1.50 per carat.

"Synthetic hyacinth"—$1.25 to $1.75 per carat.

"Synthetic blue spinel"—$0.50 to $1.00 per carat.

It should be noted that with possibly one exception, the above figures are lower than the cost of cutting corundum gems in this country.

In buying corundum gems, it should be remembered that for a given weight they are about 15% smaller than the diamond.

POSSIBILITY OF MANUFACTURING OTHER GEMS IN THE SAME WAY AS THE RUBY.

The question is often asked: "Why cannot other gems, the emerald for instance, be made in the same fashion as the ruby?" It is possible that some may be so made, but it is doubtful whether it would pay to fabricate many gems in this way as the natural stones are in little demand at low prices. In the case of more valuable stones, like the emerald, the attempt to manufacture them by similar methods has resulted in failure since the boules are amorphous instead of crystalline. We are forced to admit that some minerals require different conditions for their crystallization than others, some forming at low, and others at high, temperatures, a few—including corundum—at low, and many at high, pressures.

It may be accepted as an indisputable fact that all the so-called reconstructed, scientific, or synthetic stones on the market, with the exception of those mentioned, are either nothing but glass or are some form of doublet.

SPECIAL NAMES FOR THE CORUNDUM GEMS.

Some attempt has been made to require the use of distinctive names for the artificial gems, such as rubine and sapphirine. It seems to me that nothing could be more foolish. Why should anyone care whether a stone is natural or artificial as long as it is beautiful and permanent? The difference is wholly one of sentiment. If one has more money than he can use, he can always secure a natural stone from first-class jewelers. They will guarantee it to him as natural, and he is welcome to any satisfaction that this may give him. It would be about as logical to require the use of the terms icine and indigoine!

JAPANESE CULTURED PEARLS.

I do not wish to close without mentioning a product partly artificial and partly natural, which is being increasingly used in jewelry. I refer to the Japanese cultured pearl.

Although the process is patented, a few of the minor details of the method by which these pearls are made have not been made public, but the scheme followed is substantially as follows:

Three-year old pearl molluscs which have been carefully cultivated and protected are removed from the sea and hemispherical pieces of mother-of-pearl are placed with their curved surfaces upwards between the mantle and shell of each mollusc. How they are fastened so that the oyster cannot expel them is not revealed. The molluscs are then replaced in the water where they remain for at least four more years. At the expiration of that period, they are again removed and the upper surfaces of the previously inserted pieces are found covered with several layers of pearl nacre. The pearls thus formed are removed and curved pieces of mother-of-pearl are cemented to the lower surfaces in order to make the pearl-like objects more nearly spherical.

These cultured pearls can only be used in settings which hide the relatively dull-lustred back; they are shaped like an oblate spheroid instead of being perfectly spherical; and their lustre is apt to be more iridescent than that shown by most pearls. They are very beautiful objects, however, and are to be had in most of the tints obtainable in entirely natural pearls.

Fig. 3 is a section through the finished product showing the method of attaching the back.

These cultured pearls cost $1.50 to $2.50 per grain, wholesale, and are extensively used in Europe in very fine jewelry. In this country, the demand for them is not so great, but is steadily increasing as a result of the extensive advertising campaign inaugurated by L. Heller & Son who are the exclusive wholesale distributors in this country.

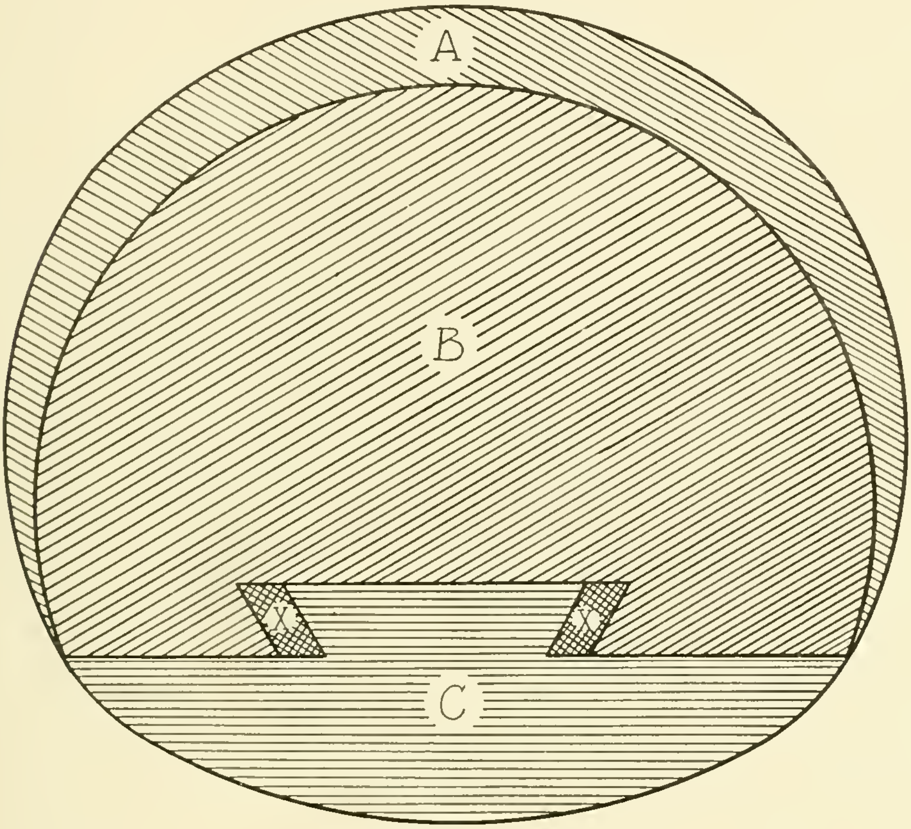


Figure 3.

A. Pearl. B. Mother-of-Pearl Placed in Shell. C. Mother-of-Pearl Back. X. Cement.

All the cultured pearls on the market are produced by a Mr. K. Mikimoto in the Bay. of Ago on the coast of Japan. Women divers are employed almost exclusively and the first crop was gathered in 1898. For several years the supply was so limited that little attempt was made to create a demand for the pearls, and the fact that they are now so largely used speaks well for their intrinsic merit. Mr. Mikimoto has recently announced that he has succeeded in producing perfect, round pearls, but none are yet on the market and the process has not yet been described.

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VOL. X. pp: 185-202.

THE ELECTRON THEORY.

By HARRY A. CURTIS.

Read at the Meeting of the Society, February 3, 1912

INTRODUCTION.

This paper presents a very brief and incomplete account of the development of the Electron Theory. It may seem superfluous to restate here what already has been so admirably stated in the various text-books on the subject, but many who are more or less familiar with the physical sciences have very little knowledge of this theory, or of its scope and importance. There is nothing original in this paper except the arrangement of the matter, and the only responsibility which rests upon its author is that which arises from an attempt to present such a tremendous topic in so short a paper.

The Electron Theory, like all other great theories of physical science, rests upon the substantial foundation of experimental evidence. It is not the product of a single genius, but is built upon the results secured by a host of experimenters. It does not draw its material from the single realm of physics, or of chemistry, or of geology; but from all of these. It does not upset and revolutionize, but coordinates. As one author has said, "The electron dropped into the supersaturated solution of electrical facts and speculations, and formed the condensation nucleus necessary for crystallization." We regard the Electron Theory as a product of modern science, and so it is if we include the last fifty years in our term modern; but in doing this we must remember that in most of the sciences fifty years carries us back into medieval history. No one claims that the Electron Theory, or any other theory for that matter, is the final expression of the truth, but this we do know: that no theory could so square with such a multitude of facts as does the Electron theory unless it be at least a fair approximation to the truth. The names which we most often meet in the history of this theory are by no means unfamiliar to us: Hittorf, Plucker, Lorentz, Crookes, Hertz, Arrhenius, Thomson, Curie, Rutherford, Boltwood, etc., etc., all men who have contributed greatly to modern science in other fields. If authority carries conviction, then certainly we must accept the Electron Theory. All in all we may say, with reasonable conservatism, that the Electron Theory is the greatest theory in modern science, and that in the future no treatise on light, heat, electricity, chemistry, geology, astronomy or biology will be accepted which does not reckon with it.

In discussing the development of this theory, we shall have to begin at a number of widely separated points and follow the lines of evidence only far enough to show that they are all converging upon one point—the Electron Theory.

Maxwell's Theory of Light.

The name of Michael Faraday occurs so often in every text-book of physics that it seems fitting to introduce almost any topic of this science with a reference to the brilliant Irish experimenter.

Faraday was not blessed with a deep mathematical knowledge, and it was often necessary for him to visualize conditions in order to follow the progress of an experiment. Thus, in order to think of the electric field surrounding a charged body he conceived "lines of force" extending into the ether from the charged body. These lines of force he considered to be in a state of tension along their length and repelling each other laterally. He was able to express and explain many electrical phenomena in terms of this conception, and it remains to the present day an indispensable mode of expression for many electrical phenomena. When Maxwell began the development of his theory of electricity and light he borrowed Faraday's ideas, but with his superior mathematical power found it unnecessary to visualize all of his results, and left his theory tied up in a maze of mathematical expressions which serve us today only because we have produced physicists with both mathematical ability and skill enough to test his theory experimentally. In recent years also Sir J. J. Thomson applied Faraday's conception quantitatively, and showed how amenable the scheme is to mathematical treatment.

That there is an intimate connection between optical and electrical phenomena was one of the theories which Faraday sought to prove. In the course of his experiments he discovered the phenomenon known today as the Faraday effect, which is the rotation of the plane of polarization of a beam of plane polarized light when it passes through a magnetic field. This effect Faraday was not able to explain, nor was Maxwell able to account for it by means of his electromagnetic theory later.

Maxwell, as we have said, began his work where Faraday left off. Light vibrations, said Maxwell, are but transverse vibrations of the Faraday lines of force, which necessarily stretch out through all space. From this standpoint Maxwell developed his theory, a theory which modern science has modified but slightly.

At the time Maxwell published his theory of light, there were certain phenomena which were not in agreement with it. The most notable discrepancy was that between K, the dielectric constant of a medium and η^2, where η is the refractive index. Maxwell's theory requires that these shall be equal. Experiments show that for many substances they are widely different. Moreover, the theory required that $\eta^2 a = \delta T$ for electric conductors, where η is the refractive index, a the coefficient of absorption, δ the conductivity, and T the period of the incident light. Here also experiment and theory were at variance. In general the situation seemed to be about this: so long as the light passed through a vacuum, the agreement between theory and experiment was excellent, but discrepancies arose as soon as material media entered into the phenomena. It indicated that an extension of the theory was necessary in order to take into account the action of matter upon light vibrations. In this demand the Electron Theory took its inception.

Evidence from the Field of Optics.

In 1878 the Dutch physicist, H. A. Lorentz, made an assumption which cleared away the difficulties. He assumed that matter contains a very large number of small electrically charged particles revolving in tiny orbits with very high velocities, high enough to radiate light waves. It is these charged particles, said Lorentz, which modify light waves when they pass through matter. Lorentz assumed that the particles were both negatively and positively charged. He did not assign any value to the charge which he assumed each particle to carry, but when that question was raised the only logical answer was that each particle carried a unit of electricity, i. e., the quantity which is associated with a hydrogen ion in electrolysis. This natural unit of electricity had already been recognized by physicists. Its value had been estimated by Stoney, who divided the quantity of electricity necessary to liberate a cubic millimeter of hydrogen by the number of atoms of hydrogen per cubic millimeter. This calculation arrived at the value about 3×10^{-10} electrostatic units. To this unit Stoney gave the name electron, and the name was transferred to the charged particle which Lorentz had assumed to be present in matter. With this assumption as a working basis, Lorentz was able to clear up a number of the difficulties which had arisen under the Maxwellian theory. Theory now fell into line with experiment and gradually the Electron Theory gained ground in the field of optics.

In terms of the new theory, a conductor is a substance in which the electrons are free to travel through the substance, while in an insulator they are contained inside the molecules and cannot be dragged out by the external electric field. Refraction and reflection and absorption now find their explanation in the relation between the period of the incident light and the free period of the electrons. Selective absorption shows us that a certain electron period is characteristic of certain substances.

The Electron Theory has proved exceptionally fruitful in the field of optics. It is perhaps not too much to say that the Electron Theory, practically as we have it today, would have developed from the field of optics alone. We shall see, however, that supporting evidence from widely different sources was forthcoming, and it is to some of these other fields that we now turn.

THE DISCHARGE OF ELECTRICITY THROUGH GASES.

We are all familiar with the ordinary phenomena to be seen in the vacuum discharge of electricity—the light and dark spaces, the striations, the peculiar luminescence, etc. If now we vary the position and shape of the electrodes, still other phenomena are to be observed. For example, if we move the anode up to the middle of the tube and use a perforated plate instead of a solid one we shall find that the phenomena do not cease at the anode, but that rays of some sort pass through the holes in the anode and travel on until they impinge upon the end of the tube. Goldstein named these rays which have their origin at the cathode, cathodenstrahlen or cathode rays. We now proceed to examine these cathode rays. If we bring a magnet up to the tube, as Plucker did, we find that the rays are bent from their path by the magnetic field. If we place a little cross of mica in their path, as Hittorf and later Crookes did, we notice a shadow thrown on the end of the tube, a sharp shadow, showing that the cathode rays travel in straight lines. Concerning the nature of these rays, opinion was divided at first. The German school, led by Hertz, maintained that they were made up of ether waves, like light, while the English school, guided then by Crookes, held that the rays were a torrent of very small particles of matter.

The extreme penetrating power of the rays was the property which impressed the Germans. Lenard, a pupil of Hertz, induced the rays to pass through an aluminum window at the end of the tube. Certainly, argued the German school, material particles, even as small as the atoms themselves, could not pass through a medium as dense as a metal. But meanwhile Crookes was devising experiment after experiment which indicated that the rays were made up of material particles and in the end the English view triumphed—at least temporarily. So much settled, physicists set themselves to determine the properties of these cathode particles, or corpuscles, as Thomson called them. Particularly the charge each carried, its mass, and its speed through the tube were to be determined. In the work which now followed, Thomson was the guiding spirit. The experiments which we describe next were mostly his, although others contributed, as will be indicated.

THE SIGN OF THE CHARGE ON A CORPUSCLE.

This is negative, as was first shown directly by Perrin, who caught the corpuscles in a little metal cylinder placed inside the vacuum tube and connected with an electroscope.

THE SPEED OF A CORPUSCLE.

Of all the various methods by which this has been measured we shall mention only two, one used by Thomson and the other by d'Arsonval. Thomson used the method of simultaneous magnetic and electric fields in an apparatus which is sketched below (Fig. 1).

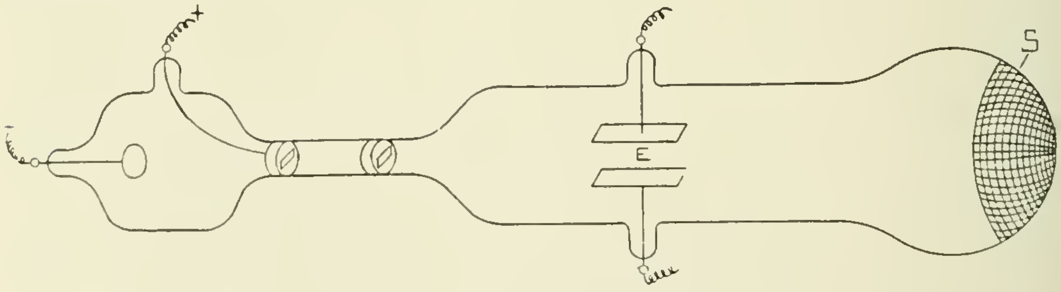

Fig. 1.

We have already stated that the corpuscles are turned from their path by a magnetic field. Thomson showed that they are also deflected by an electric field, a result which we should expect, if the particles are really charged. The two fields were arranged so that one of them would deflect the particles upward, the other downward. The strengths of the fields were then adjusted so that no deflection of the particles was produced. The speed of the particles can then be estimated as follows:

In a magnetic field the force acting on a current is $H \times C$, where H is the magnetic field strength and C the current. Our current is ev, where e is the charge carried and v the speed. The force deflecting the particle is then Hev. In an electric field the force acting is Xe, where X is the electric field strength and e the charge. When there is no deflection of the particles these two forces must be equal, or $Hev = Xe$, whence $v = \frac{X}{H}$. Since the values of X and H are easily measured, we have the speed v. This experiment of Thomson's gave a value ranging from ten to twenty thousand miles per second, the highest velocity which had ever been observed for material particles, a velocity beside which the speed of a rifle bullet is slow.

The apparatus used by d'Arsonval is represented in Fig. 2. The pencil of cathode particles C is deflected from its path by the electromagnet A. This magnet is operated by an oscillating current, so that the deflection is first downward and then upward, causing the particles to fall in a band between the point E of maximum and the point F of minimum deviation. A screen D is then interposed which cuts off all the particles except those which fall at E. Then a second magnet B is operated so that its magnetic field is at every instant in exactly the same place in its cycle as that of A, i. e., the magnets are in exact tune. The distances between A and B is then adjusted so that B produces no deflection of the particle. This distance must be the length of the path traveled by the corpuscle while the magnetic fields have passed from maximum strength, as they were when the particle passed A, to zero strength, the only time when the magnet B will not produce a deflection of the particle as it passes. D'Arsonval used a current having a frequency of 10,000,000 oscillations per second. The particle must then have traveled the distance from A to B in one forty-millionth of a second. D'Arsonval's measurements checked those of Thomson.

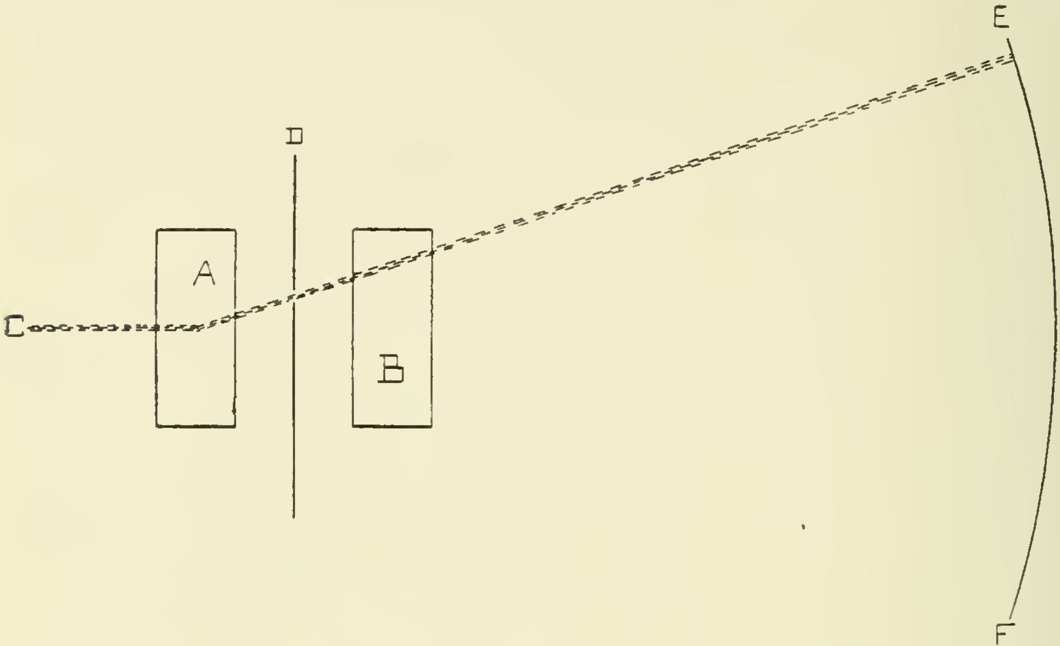

Fig. 2.

The Ratio of the Charge to the Mass of a Corpuscle.

There are likewise many ways of measuring this quantity. We may calculate it, as Thomson did, from measurements made with the apparatus used for determination of the velocity of a corpuscle. Suppose that l in Fig. 3 is the length of the electric field of uniform strength X through which the particle travels in the apparatus referred to. If v is the velocity of the particle, it will travel this distance in a time $\frac{l}{v}$ and will gain a velocity of $\frac{Xe}{m} \times \frac{l}{v}$ in the direction of the positive plate. At the end of the path l the particle will have been deflected through a distance $\frac{Xe}{m}\frac{l}{v}\frac{l}{v}$. The angle θ between the old and the new direction will be such that $\sin\theta = \frac{Xel^2}{lmv^2} = \frac{Xel}{mv^2}$. (When θ is small the angle θ may be used instead of the $\sin\theta$). Solving the above equation for $\frac{e}{m}$ we get $\frac{e}{m} = \frac{\sin\theta\, v^2}{Xel}$. With v known we may now find this ratio by substituting in the measured values of X, θ and l used in the experiment. In Thomson's experiments he first found the ratio to be $2{\cdot}3 \times 10^{17}$. Later and more accurate measurements have established a value of $5{\cdot}6 \times 10^{17}$ electrostatic units or 1.9×10^{7} electromagnetic units.

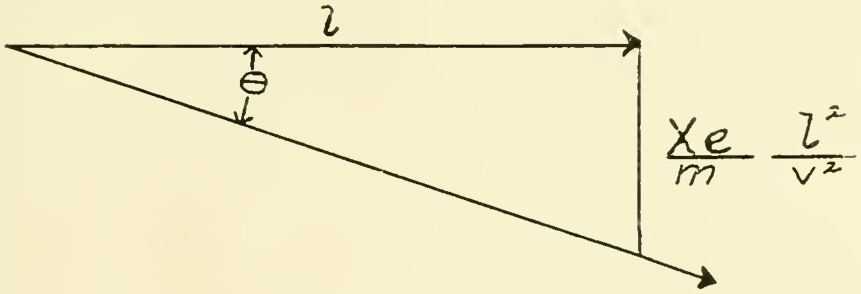

Fig. 3.

We may also calculate the ratio of e to m for the corpuscle, after the velocity has been measured, by noting the fall of potential between the anode and cathode. If this be V, then the energy impressed upon the particle will be eV. This must be also $\frac{1}{2}mv^2$, and we can equate the two expressions and solve for the ratio.

The remarkable thing about this ratio is that it is about seventeen hundred times as large as the ratio of the charge to the mass for a hydrogen ion. From this fact we must conclude either that the charge on the corpuscle is seventeen hundred times as large as that on a hydrogen ion, the mass of the two being the same, or that the mass of the corpuscle is one seventeen-hundredth that of a hydrogen atom and carries the same charge, or else that both charge and mass of the corpuscle are different from those of the hydrogen ion. In order to decide which of these three propositions is true, it is necessary to determine either the charge or the mass of the corpuscle.

The Charge on a Corpuscle.

It has not been possible to measure directly either the charge or the mass of a corpuscle, but Thomson has solved the problem indirectly by measuring the charge on a gaseous ion. The evidence that this is the same as that carried by a corpuscle cannot be taken up here, but suffice it to say that this fact was well established at the time when Thomson performed the experiment which gave him the charge on an ion.

A number of years ago Aitken showed that when air is entirely free from dust it can be supersaturated with water vapor to about eight-fold. The introduction of a little dust into this supersaturated air at once precipitates a cloud of water particles. Later C. T. R. Wilson found that gaseous ions serve also as excellent condensation nuclei for water drops. Of this discovery Thomson made use in solving his problem. An apparatus was devised in which any desired degree of supersaturation could be obtained by suddenly expanding saturated air. This air was then ionized by a short exposure to Roentgen rays. The excess of water vapor immediately precipitated on the ions, forming a dense cloud which settled slowly. The total amount of water vapor thus precipitated can readily be calculated from the known quantity of air and the known lowering of the temperature and pressure by the adiabatic expansion. Thomson then found the total charge on the inclosed air by measuring the conductivity. Knowing the total quantity of electricity carried by the ions and the total amount of water precipitated as drops, it is obviously possible to calculate the charge on each drop if the total number of drops can be determined. This last number was found by measuring the rate at which the cloud settled down. Long ago (1849) Sir Geo. Stokes calculated the relation between the size of a drop and the rate at which it falls through any medium of known density. Thomson measured this rate of fall, thus finding the size of the drops, and knowing their total volume he then estimated their number. Dividing the total charge on the gas by the number of drops we get the charge on an ion, making the assumption, which was verified a little later by H. A. Wilson, that each drop is condensed on a single ion. The value of the charge so determined is $3{\cdot}4 \times 10^{-10}$ electrostatic units, i. e., the same charge as is associated with the hydrogen ion in electrolysis, the natural unit of electricity.

THE MASS OF A CORPUSCLE.

Substituting this value of e in the equation $\frac{e}{m} = 5{\cdot}6 \times 10^{17}$ we get $m = 6{\cdot}1 \times 10^{-28}$ grams,* roughly seventeen hundred times smaller than the hydrogen atom.

We can readily see now that particles of this size, traveling at the rate of twenty thousand miles per second, would fly through ordinary matter as a flock of birds might fly through a squadron of balloons.

CORPUSCLES AND ELECTRONS.

It now becomes our task to establish the identity of the corpuscle and the electron. Lorentz had merely assumed that matter contains small charged particles which are concerned with optical phenomena and which carry the electric current through a conductor. In the vacuum tube we actually find charged particles being liberated from the material of the cathode and flying through the tube under the stress of the external field. By actual experiment we find that each of these corpuscles is charged with a unit of electricity—the very charge which Lorentz had assumed for his electron. Moreover, these corpuscles in the vacuum tube are the same, no matter of what material the cathode may be made. It would seem a fair guess, indeed, to say that the electron of Lorentz is the corpuscle of Thomson. But if it were possible to determine the ratio of the charge to the mass for an electron and compare it with the value assigned to this ratio for a corpuscle, in finding these the same we should feel that we had entirely convincing evidence as to the identity of these two particles. Now, it is this very ratio which *was* determined for an electron, just a few months before Thomson did the same for the corpuscle. We now proceed to discuss this experiment from the field of optics.

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*Recent measurements arrive at the value $e = 4{\cdot}83 \times 10^{-10}$.

THE ZEEMAN EFFECT.

In 1896 Zeeman observed a slight broadening of the D_1 sodium line in the spectrum when the source of light was placed between the poles of a powerful electromagnet. When this discovery was published Lorentz was at once able to explain it by means of his electron theory. Moreover, he was able to predict that the fact of the case was that there was a resolution of the spectrum line into either two or three lines, according as the light was viewed at right angles to the field, or in the direction of the field. Further, said Lorentz, the two lines should be circularly polarized in opposite directions, and in the case of the three lines all three should be plane polarized. This prediction was found to be in entire accord with the facts, although in most cases the resolution of the spectral lines is not so simple as we have indicated.

Lorentz argued that if the light were really being radiated by electrons revolving in orbits, then a magnetic field would shorten the orbits of the electrons revolving in one direction, thus increasing their frequency of revolution, while it would increase the orbits and lessen the frequency of the electrons revolving in opposite direction. We should then have, in place of the original light wave, two light waves, one longer and one shorter than the original wave. This would give us two lines in the spectrum, one on either side of the original position. In case the light is viewed in the direction of the field there will also be one line in the position of the original line, for the electrons vibrating in the line of the magnetic field will not have their orbits or periods changed. The discovery of the Zeeman effect, and the agreement between facts and the predictions of Lorentz, greatly strengthened the position of the electron theory in the scientific world. But the discovery was of further great value in establishing the ratio of the charge to the mass of the electron, for it is possible to calculate this ratio by measuring the amount by which the spectrum lines are separated by a magnetic field of known strength. Using Zeeman's results Lorentz calculated that this ratio was $6{\cdot}1 \times 10^{17}$, approximately the same value which Thomson found a little later for the corpuscle.

We have said that Perrin proved the corpuscle to be a negatively charged particle. By noting the direction of circular polarization of the shorter wave length in the Zeeman effect, it was shown beyond dispute that the particles which are concerned in the Zeeman effect, i. e., the electrons, are also negatively charged.

Perhaps the chain of evidence as to the identity of the corpuscle and the electron is not yet complete enough to settle the question beyond all dispute, but it must be admitted that such evidence as we have certainly points to that conclusion. Let us then, for the time at least, cast our lot with the credulous and say that the corpuscle is an electron, and from this point on speak only of the electron.

Many questions now occur to us. Are these electrons merely scattered in amongst the atoms, or are the atoms themselves made up of electrons? Perhaps each atom is a little solar system of electrons, revolving in their orbits in periods such as to give rise to the well known spectrum lines. This last view is an attractive one; have we any experimental evidence that such is the case? We have. It is just this that the spectroscope teaches us, if nothing else. Have we further evidence? Let us turn to our next topic.

RADIOACTIVITY.

In 1896 Henri Becquerel noted two very interesting properties of uranium salts. First, they ionize the air in their neighborhood, so that an electroscope can be discharged by bringing a little uranium salt near it. Second, they give out some kind of radiation capable of affecting a photographic plate through substances opaque to ordinary light, such as black paper. Becquerel called this new property of uranium radioactivity. It was soon found that other materials are radioactive, and in the following year the Curies in Paris began a systematic examination of radioactive bodies, which finally resulted in the isolation of two exceedingly radioactive substances. One of these they named polonium, the other radium. Since then a number of very active radioactive elements have been discovered, and it seems likely that all matter is radioactive to some degree; but since radium is a typical element of this class, we shall use it for our discussion. Chemically, radium is one of the alkaline-earth metals, closely resembling barium and having an atomic weight of 226·4. It is about two million times as radioactive as uranium, although not the most radioactive substance known.

Let us now examine this phenomenon of radioactivity more closely. It was early noted, by Rutherford, that the rays from radium consist of at least two different kinds, one, named the β rays, made up of very small, negatively charged particles; the other, called the α rays, of much heavier particles, positively charged. We cannot take the time here to review all of the tremendous amount of experimental work which has been done upon radioactivity; we shall content ourselves with merely stating final conclusions as far as they have been reached.

The β rays are a stream of electrons, shot off from radium with tremendous velocities, some as high as 95% that of light waves. The β particle carries the same charge and has about the same mass, as the electron, and behaves very much like it under all circumstances. The β rays ionize the air for some distance from their source.

The α rays consist of particles of atomic size, each particle carrying two positive charges. The α particle is an atom of helium. That helium is produced continuously from radium is a fact that cannot be assailed, but not all experimenters agree as to the identity of the α particle and the helium atom. The velocity of the α particle is seldom higher than ten thousand miles per second, but its mass is so large compared to that of the electron that it does a great deal of ionizing in a gas before it is stopped. It is estimated that each α particle produces about 86,000 ions of air.

Radioactivity is an atomic phenomenon. This fact was established experimentally mostly through the work of Rutherford, although the idea seems to have occurred to many experimenters at about the same time. In radioactivity we are witnessing a disintegration of the atoms of radium. Every second of time a certain average number of radium atoms break up, helium atoms are formed, sometimes electrons shoot away with stupendous velocity, and there remains a new system of electrons, an atom of simpler construction than the radium atom. This new atom is that of a new element to which the name niton has been given, and you will find it given an atomic weight of 222·4 in your 1912 International Atomic Weights. This element niton (radium emanation) is an inert gas of the argon family. The atomic disintegration does not end here, however, for niton itself is disintegrating, forming again a new element, this time a solid which is called radium A. Radium A in turn decomposes into radium B, this into radium C, etc., etc. What the end product may be we do not know, but there is some evidence that radium F, which is polonium, decomposes into lead. Theoretically, each of these products is an element, but of these only niton has been prepared in sufficient quantities so that the determinations of density, atomic weight, specific heat, etc., could be made in order to entitle the new element to a place in the atomic weight table.

There is considerable evidence to indicate that radium itself is a disintegration product of uranium.

How do these facts of radioactivity fit in with our guess as to the structure of an atom? What more natural than to think that a system of electrons—an atom—would occasionally become unstable and upset, some of the electrons shooting off at tangents, others grouping themselves into a new, simpler, and more stable system? Which atoms would be the most likely to break up? Those having the most complex systems. Which elements are radioactive? Those of highest atomic weight—radium, uranium, thorium, etc.

Thomson has examined mathematically the stability of various systems of electrons revolving in a sphere of positive electricity, and has arrived at some interesting results, but we must pass them by here, with only the remark that Thomson has pointed out the possibility of explaining the regularities of the periodic table of the elements in the repetition of the same geometric configuration of the electrons in the atoms. This is at least a step in the right direction, for it is evident that so long as we regarded the atom as the final division of matter there was no hope of ever explaining the table of Mendeljeff. There is one more point we might mention in passing. It can be shown mathematically that in such systems of electrons as we have postulated, the small atoms would be likely to capture electrons from the larger atoms. On this basis, the larger atoms should be the most electropositive. As a matter of fact the elements which have the highest atomic volumes (atomic weight÷specific gravity) are those which are most strongly electropositive.

ELECTRIC MASS.

Thirty years ago Thomson published a mathematical memoir, showing that an electrically charged body in motion should have a greater momentum than when moving with the same velocity without electric charge, i. e., an electric charge in motion has a kind of mass. No one at that time foresaw the great importance which this paper was destined to have, for the reason that it was easily shown that for ordinary bodies, even though heavily charged and moving with high velocity, the added electric mass would be far below the accuracy of any known instrument. Even though a hydrogen ion could be moved with the velocity of a rifle ball, the electric mass would be entirely imperceptible. When, however, the β particle was discovered, it was calculated that here the electric mass should be discernable, i. e., the particles moving with the highest velocities should have the greatest apparent mass. The measurements were made with great care by Kaufmann of the Gottingen laboratory in 1902, and it was found that such indeed was the case, the apparent mass increased with the velocity. But the surprise was yet forthcoming; for, when calculations were made from these data to determine what part of the total mass was electric, it was found that *all* the mass was electric. In other words, our β particle, our corpuscle, our electron, are no more than unit electric charges in very rapid flight. What then of our atom? Is its mass only the mass of the electrons? Well we have not yet accounted for positive electricity, whatever we mean by that term.

POSITIVE ELECTRICITY.

What is positive electricity? Is it only the phenomenon of the absence of negative electricity, just as cold is the absence of heat? Does it have mass?

Recently Thomson said that he does not know what positive electricity is, and certainly no one knows more about positive electricity than does he. We never find positive electricity separated from matter, and we never find it associated with particles of matter smaller than atoms. Thomson has been working a great deal on the problem in recent years, and has made some very valuable contributions to various lines of physics and chemistry, but does not seem much nearer to the solution of the problem of positive electricity.

If we leave positive electricity out of the question, then our hypothetical atom, made up only of a system of electrons, is purely electrical, and we have explained away matter entirely. To be able to do this seems to be the goal toward which we are striving, but at present they are but dreamers who say flatly that matter is only electricity. Our minds are always impatient of the restraint which science places upon them, but we can only hope to make real progress in physical science by carefully noting the point at which we part company with experimental facts. In our discussion of the electron theory we have tried to indicate just how far our ideas were supported by experimental facts and what part was merely speculation.

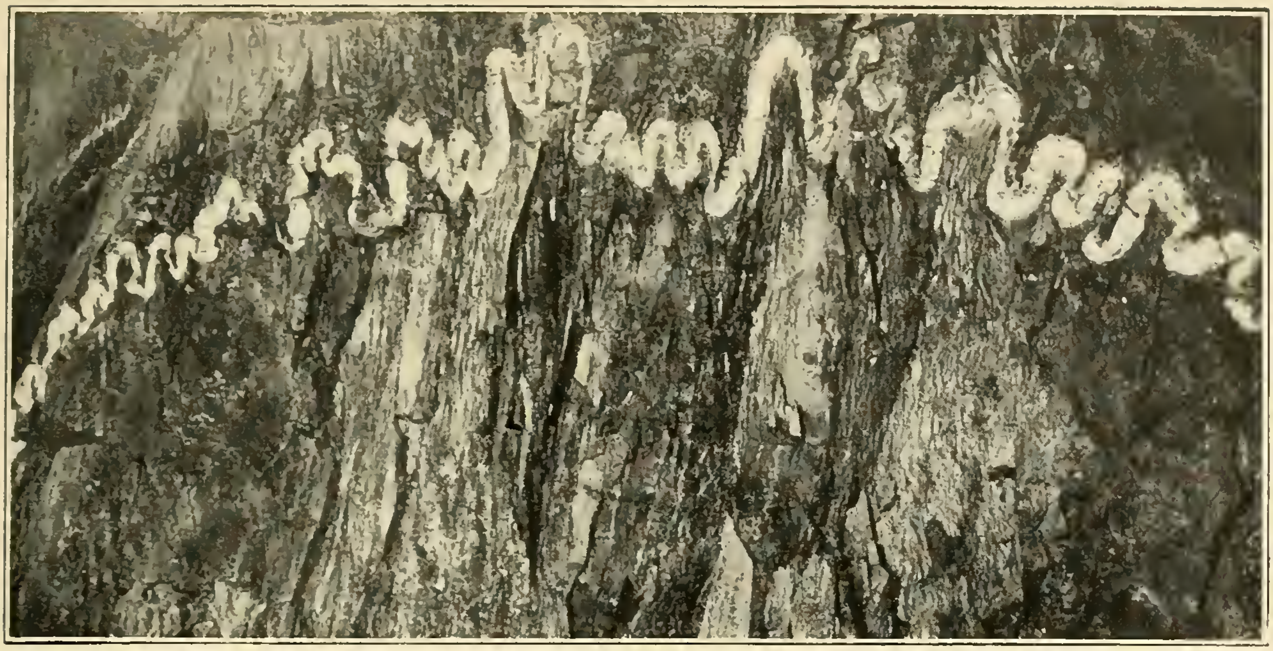

Plate I. Fig. 1.

Plate I. Fig. 2.

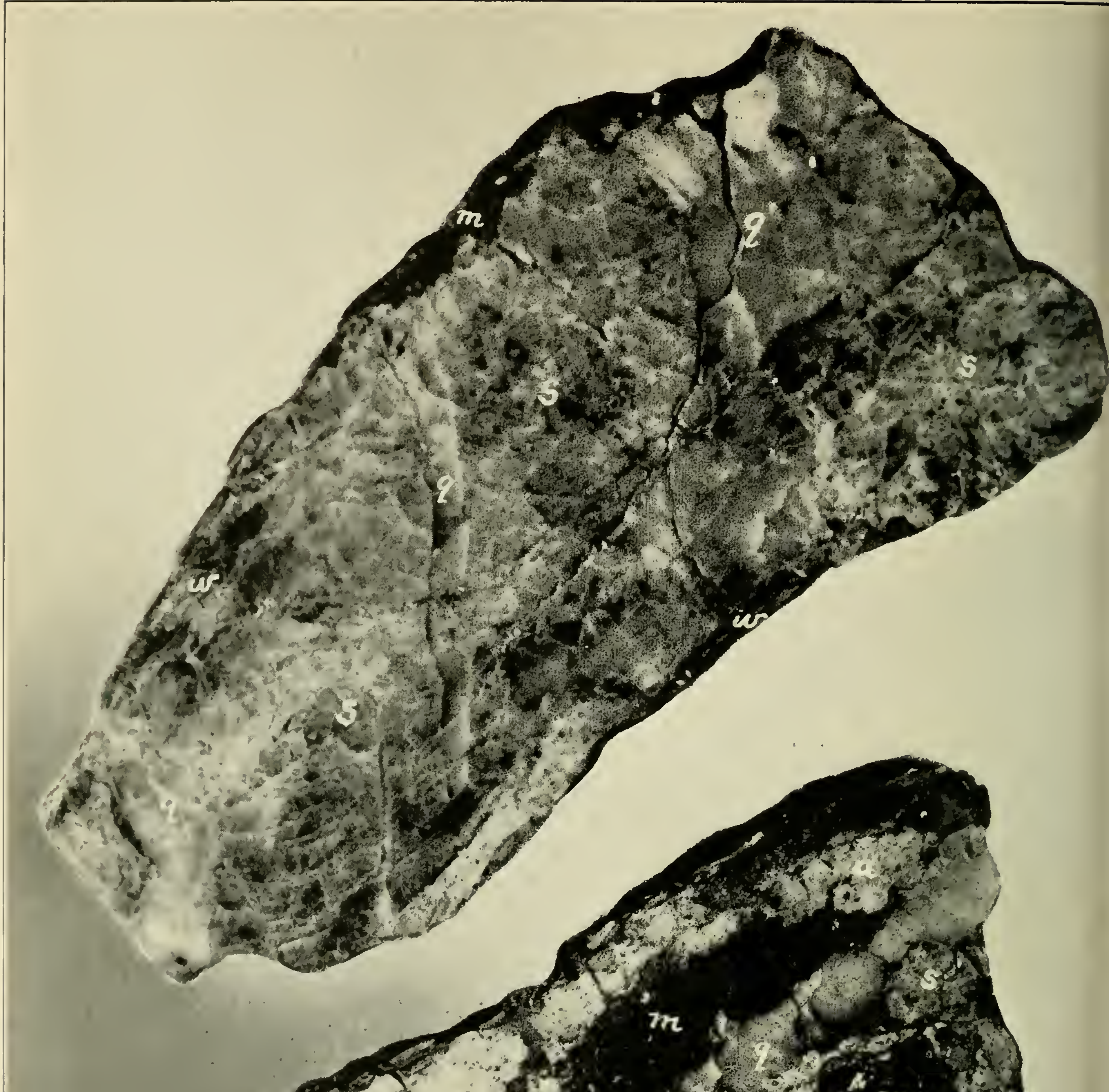

PLATE II. Figures 3 and 4. Natural Size.
s. Scheelite. q. Quartz. m. Mispickel. a. Ankerite. w. Slate Wall-rock.

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY
VOL. X. pp: 203-210.

TUNGSTEN MINING IN NOVA SCOTIA.

By Victor G. Hills.

Read at the Meeting of the Society, October 5, 1912

Since Boulder County, Colorado, furnishes eighty per cent of the tungsten product of the United States and twenty per cent of the product of the entire world, it is fitting that the proceedings of our Society should occasionally contain something on any phase of the tungsten industry.

This article will treat of the tungsten deposit of Nova Scotia from the viewpoint of the Colorado miner, and of the special phases wherein the ore, and the mining and the milling of it there, are different from those that we are familiar with here.

The scheelite deposit here referred to is the only tungsten mine in Canada. Tungsten has been found in many places in Canada, as it has all over the world; scheelite is found in at least two other counties in Nova Scotia; and hübnerite is known in Cape Breton Island; scheelite is found in Beauce County, Quebec, and at the Victoria mine in Ontario; both wolframite and scheelite are found in the Kootenay District, B. C.; but at no other place has the mineral yet been disclosed in anything like a commercial quantity.

Location and Geology.

The location of Scheelite Camp is not shown on any published map. It is located in the central part of Halifax County, Nova Scotia, twelve miles from the Atlantic coast and 34 miles from the nearest railroad point. It is two miles west of the old Moose River Gold Mines, and surrounded by forest abounding in lakes and swamps. The country is substantially level and some 400 feet above the sea.

Nova Scotia has been a gold mining country, in a modest way, for some 50 years, and there is plenty of literature on its geology and its peculiar vein formation. To understand the nature of the veins it may be well to recall briefly that the Nova Scotia peninsula consists of granite and Lower Cambrian quartzites and slates; the latter being in a series of folds parallel with the Atlantic coast. The quartzites are dark colored and evidently contain much felspathic material. Layers of the hard, pure type are rare. This impure quartzite has received the name "whin" by the miners throughout the Province; and, while it is an inexcusable misnomer, since whin is an igneous rock, its use is so general that it is unavoidable about the mines and is often seen in print in Nova Scotia mining articles. The name "graywacke" fits this rock, but the term is now obsolete.

The veins carrying the scheelite are of the same formation and character as the gold-bearing veins. They are of quartz layers interbedded or intercalated with the sedimentaries and parallel with them throughout their folds. As a general regional formation their like, I believe, is not known in the metal mining world excepting the famous "Saddle Reefs" of Bendigo, Australia, with which they are practically identical in formation. A description of the Bendigo veins is given by Mr. T. A. Rickard in the Transactions of the American Institute of Mining Engineers, Vol. XX, p. 463; Vol. XXI, p. 686, also Vol. XXII, p. 289. The Nova Scotia veins exhibit a peculiar compound folding; the veins themselves being crumpled within the larger folds of the original sedimentary strata. See Plate I, Fig. 1. Fig. 2 on the same plate shows a vein on the flank of a fold where it is nearly vertical, and is stripped ready for breaking.

Different theories have been advanced to explain this most peculiar vein formation. The main point of disagreement is whether the quartz veins were formed before or after the folding. The Proceedings of the Canadian Mining Institute for its meeting last March contains a paper by Mr. T. A. Rickard on "The Domes of Nova Scotia," and another paper by myself on "The Scheelite Deposits of Nova Scotia." Both of these articles give considerable attention to the peculiarities of these crenulated veins, and present different theories. Mr. Rickard's views correspond substantially with those of Mr. J. E. Woodman (Trans. Nova Scotia Inst. Sci., 1903, XI, p. 67), which are that the quartz veins are fillings of zigzag fissures formed after the folding was substantially complete, with the sharp corners rounded by chemical action. My observations agree more nearly with those of Mr. E. R. Faribault of the Canadian Geological Survey, that the veins were originally formed as substantially horizontal pancake-like lenses of considerable extent between the sedimentary strata, as openings were gradually made as a result of horizontal pressure, and that afterward these veins were crumpled into their present form by the crushing of the enclosing soft slate between sliding beds of the harder quartzite. The discussion is lengthy and complicated and requires reference to numerous photographs and sketches, and no attempt will be made to review it here.

The veins bearing the tungsten ore are in the same system and on the same anticline as the old Moose River Gold Mines, two miles distant. The scheelite veins had been prospected for gold years before, as shown by trenches overgrown with brush. A little scheelite was found in the old gold mines at Moose River; but so far no gold, above a trace, has been found in the tungsten mines.

The vein matter consists substantially of quartz, scheelite, ankerite, and arsenopyrite. There is a little pyrite and calcite, and a few slender black tourmaline crystals which appear in the other four common minerals. The specimens photographed for Plate II, shows the four chief minerals and a tourmaline crystal. Fig. 3 is mostly scheelite, and Fig. 4 has an excess of the mispickel, but is more typical of the ore deposit.

The scheelite seems to be strictly a primary deposit. Not a particle of either of the black tungsten ores has ever been found in these veins; and such an occurrence would be looked for if the tungsten ore was formed as an alteration and replacement of the ankerite which contains the very elements necessary to form wolframite. Further, no partly altered specimen has ever been found, and where scheelite occurs touching the ankerite there is a distinct line of demarkation between the two. See Fig. 3. That the scheelite and mispickel were the earliest minerals deposited is plain, as they are frequently found brecciated with the fractures filled with quartz, as shown also in Fig 3. Occasionally lime spar occupies the fractures.

On the question of the genesis of ore deposits, which has occupied so much of the discussion of the technical mining world for the last fifteen years, and referring particularly to the controversy between the "fire men" and the "water men" as to which was the predominating agency in the deposition of ore-bodies, I have always regarded Prof. Kemp's "The Role of the Igneous Rocks in the Formation of Veins" (Trans. Am. Inst. Mg. Eng., Vol. XXXI, p. 169), as well nigh the keynote of the situation. Most of the tungsten deposits of the world are in granite or at a granite contact. While this district is miles from any surface exposure of granite I am inclined to think that the granite is at no great depth below this deposit.

According to the "Records of the Geological Survey of India," there is a strong likeness between the wolframite occurrence of Central India and the scheelite of Nova Scotia.

A tungsten deposit which I examined at Jardine, Montana, consists of scheelite in quartz veins. The veins are fissures in mica schist. The occurrence is in an old gold mine. The scheelite is found in the same veins, but in separate ore-shoots from the gold.

The discovery of tungsten in this locality was made in the fall of 1907, by a trapper who picked up a piece of the scheelite in the bed of a small brook. He did not know the nature or value of his find. Some development work was done during the short summer seasons of 1909 and 1910.

CONSTRUCTION AND OPERATION OF MILL.

On March 1, 1911, I took charge of the property to develop the mines and build a mill. Foundations for boilers and air-compressor were begun by blasting in frozen ground. The lumber for building was made with a portable saw-mill from trees cut in the nearby woods. There was neither clay nor sand for brick, mortar, or concrete. Brick was hauled in on sleighs at a cost of $30.00 per thousand; also some sand was hauled 18 miles by sleighs. Later, when the river was clear of ice, sand was made of quartzite boulders by crushing in an old water-power gold stamp-mill found two miles distant. A wagon road had to be built into the camp when the ground was thawed out enough to permit it. The best English Portland cement and Scotch fire-brick were readily obtainable at Halifax, but the 34 mile wagon haul for these things and for the machinery made construction tedious and slow, and the year 1911 was consumed before the mill began producing concentrates.

A modest but substantial mill was built to treat one ton of crude ore per hour. I outlined a flow-sheet to take advantage of every inexpensive device to prevent sliming. The ore was dumped over a grizzly before going to the crusher. The roll feed was washed by a spray so that only the clean coarse material went to the coarse rolls. Rolls were used for crushing, as being undoubtedly better than stamps or any other form of screen-faced pulverizing mill to avoid sliming.

While the scheelite is more friable than either the quartz or the ankerite and, as usual in the concentration of all tungsten ores, the main loss is in the slime tailing, yet this loss with scheelite is somewhat less than with our Colorado black ores. The walls of the vein are slate which makes an enormous amount of slime and augments the difficulties of handling this portion of the pulp. This must be remembered when considering the loss in slime tailing.

In milling, since scheelite and mispickel have the same specific gravity—6·0—they together form the concentrate from the tables. The pyrite is just enough lighter to enable it, for the most part, to be thrown out with the tailing.

The raw concentrate consists of some 45 per cent mispickel coming partly from the vein and partly from the slate wall-rock. To get rid of the arsenic it was necessary to roast and treat with a magnetic separator. This phase of tungsten milling, of course, does not appear in our Colorado work.

ROASTING FOR MAGNETIC SEPARATION.

For roasting, a Wilfley revolving hearth furnace was built. It proved quite satisfactory. For treating separately numerous small lots of both coarse and fine material, and particularly where the furnace can not be kept in steady operation, I know of no roaster that would be more desirable. The literature on the subject of ore-roasting seems to be notoriously meager in reference to the degree of heat used in connection with the time of exposure. I found that this mispickel was decidedly better prepared for the magnetic separator by a high temperature and short exposure. Thus, 1500 degrees F. for 50 seconds gave better results, for example, than 1100 degrees for 90 seconds. The tests which had been made on roasting this ore at the Kingston School of Mines had evidently proceeded on the idea of burning off as much of the arsenic as possible; but this idea was all wrong. The best separation of the arsenic can be made by the least possible roasting that will render the iron magnetic. The arsenic can then be removed with the iron.

A Dings single-magnet separator made an excellent, clean separation. The magnetic part carried an average of 0·72% WO_3, with some lots as low as 0·42%. The non-magnetic product carried only 0·34% arsenic. And these returns could, if necessary, be further reduced by using a two magnet separator or by running through a second time. The separator operated at 8 amperes.

The finished product carried, besides the 0·34% arsenic, a little sulphur and phosphorus. Otherwise the concentrate contained no deleterious element. While no other tungsten ore in the world compares with our Colorado product for freedom from undesirable elements, this Nova Scotia product is quite within the general market requirements and compares favorably with the tungsten ores from most parts of the world.

With my trial run the mill saving was 86·8%. Remembering that, besides the excessive amount of scaly slate gangue, augmenting the slime loss, this concentrate has to be subjected to a second loss from flue dust in roasting and a third loss from magnetic separation, I regard this as a good saving. The market product carried 70% WO_3. That this is higher than the average of our Boulder county product is, of course, due to the higher tungstic acid content of the lime tungstate. The coarser table products at Scheelite would run as high as 73% WO_3. A test on this ore made at the Kingston School of Mines reported a saving of 89·5%; but the ore was sorted nearly free from slate and the method used was impracticable to apply in a small and simple mill. Additional mill equipment introducing coarse jigs, regrinding of middlings, and more slime settling capacity, would materially increase the saving. It is the old mill problem; to determine whether the additional saving would pay for the outlay necessary to produce it.

APPENDIX.

THE TUNGSTEN OCCURRENCE AT LOON LAKE, WASHINGTON.

In July of this year I visited the tungsten mines located six miles northeast of Loon Lake, Stevens county, Washington.

The ore is hübnerite occurring in interbedded quartz lodes in quartzite at and adjoining a contact with granite. It occurs more in coarse particles and less in bladed forms than is usual with this mineral. There is no other mineral present approaching the hübnerite in specific gravity, and the concentrating mill makes a very clean and high-grade product.

The development of the district is as yet quite limited; but plentiful float, consisting of coarse hübnerite in quartz is found for about half a mile along the quartzite-granite contact.

DISCUSSION.

Mr. R. C. Hills—The geologic structure of the scheelite deposits of Nova Scotia, as described by Mr. Victor G. Hills, strongly resembles that of the ore occurrences of Summit District, Colorado, described in the first volume of the proceedings of this Society.

The lithological and mineralogical associations of the two occurrences are, indeed, wholly dissimilar. In Nova Scotia the minerals are scheelite, pyrite and arsenopyrite with ankerite and quartz, lying conformable with crumpled lower cambrian sediments. In the Summit District occurrences free gold is associated with enargite and pyrite in the contact between rhyolite and andesitic trachyte in an abruptly folded complex of these rocks and the brecciated material resulting from the folding.

Such structure is, in all cases, doubtless the result of tangential compression and is not commonly, indeed, but rarely, associated with metal veins, though often with coal seams. Much less pronounced, yet nevertheless genetically related are the monoclinal flexures often observed in connection with bedded deposits such as those of Aspen for example. Also the dome-like structure of several iron deposits such as those of Fierro, New Mexico, and Iron County, Utah. Plication more or less pronounced is common in the mineral districts of the Great Basin, where all the north and south ranges are mainly faulted blocks.

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THE APPLICATION OF GENETIC THEORIES TO THE SEARCH FOR LOCAL ENRICHMENTS IN VEINS.

By George E. Collins.

(President's Address, Annual Meeting, December 21, 1912)

It has been customary for the retiring President of this Society, at the close of his term of office, to deliver an address, usually dealing with some subject of general interest. Of late years, these addresses have frequently been devoted to economic problems, as viewed in the light of scientific research, an example which I propose to follow.

The subject to which I shall ask you to give your attention is one of importance, not only to the miner, but almost equally so to all the inhabitants of the State. For it cannot be too strongly impressed on the general public that its interests are indirectly bound up with those of the miner. Of late years the value of our agricultural and stock output may have outstripped that of the mines; but the farmer and the cattleman should bear in mind that the mining communities constitute their steadiest and best-paying markets. But for the mines, the agricultural development of the State could not have been commenced so soon, or progressed as far as it has done.

The problems connected with the treatment of complex ores, and the economic utilization of the various metals they contain, are numerous and of the utmost importance. Yet, absorbed in his own special class of problem, the metallurgist is too apt to take it for granted that his are the only real troubles; that the miner should have no difficulty in furnishing unlimited quantities of such ores, if he for his part can only provide a solution to the question of utilizing them.

So far as this State is concerned, nothing can be farther from the truth. The aggregate mineral resources of Colorado are very great; probably as much or more yet remains to be discovered, as has been mined already. But as a rule, and comparing Colorado with some of her neighbors, the extent of her individual ore-bodies, excepting at Leadville, is not great. Our State may be said to contain many small mines, rather than a few very extensive ones. And without any intention of disparaging the ore-bodies now proved throughout the State, I will venture the personal opinion that they will not, as they stand, support our present rate of extraction for many years, without fresh discoveries. In a word, I regard the necessity for prospecting, for exploration underground, as of fully equal importance with that for study of treatment problems. Perhaps it is of greater importance, if our mineral output is to be maintained indefinitely at its present figure. Furthermore, I do not think as much intelligent effort is being directed to the discovery of new ore-bodies, as to the utilization of the old. Nor have the recent developments of science been as helpful in pointing the way to progress in this direction as in that of metallurgy.

To quote from a recent writer:*

> "There is no better indication of our ignorance of the fundamental facts of ore genesis, than our failure (here) to produce useful working theories, and there is no better proof of the present unsuitability of the so-called 'genetic' classifications to the purposes of the miner."

With this opinion I agree. In recent years novel types of ore-body have been recognized and described; and considerable light has been thrown on the physical and chemical conditions attending the deposition of ores. Once an ore-body has been accidentally discovered and sufficiently exposed, geologists of different schools hasten to label it and to formulate hypotheses, from their varying standpoints, as to its origin. By comparison of their conflicting views we can usually select by elimination a certain residuum of generally-accepted theory, which to the educated miner appeals as furnishing at least a reasonable and probable explanation of the facts as they appear to him. But it remains true that these deductions are as yet useful only in a general way. They serve to explain tentatively the origin of a metalliferous deposit as a whole; but seldom throw much light on what, to him, are questions of more immediate economic importance and more immediately absorbing interest. What are the reasons for the localization of the valuable portions of the deposit; and where are such valuable portions to be looked for? It is emphatically true that when the generalizations of economic geology are translated into the vernacular of concrete experience they commonly fail; that when the geologist is sufficiently imprudent to tell us where to look for ore he proves wrong just as often as the rest of us; and his failures are the more striking, because his deductions are often more positively expressed than those to which we, who walk warily in the light of mere experience, have learnt to confine ourselves.

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* Augustin Locke, Ore Deposits of Goldfield, E. & M. J., Oct. 26, 1912. Vol. 94, p. 800.

The recent experience of Butte, of Tonopah, or to come nearer home, of Leadville, remind us how imperfect are the observations, and how fallible the practical deductions, of the most competent and careful geologists. Yet, while the concrete predictions as to the immediate future of Butte, based on the rediscovered and reinforced theory of secondary enrichment, have been discredited by the course of development, and while we now see that the theory is less universally applicable than we all at first supposed, the theory itself stands. The science of Economic Geology advances in bounds only to overreach itself and fall back; but it never recedes quite to the starting-place. In each of the fashionable theories which from time to time spring up, there is a kernel of solid truth, which remains as a permanent addition to the stock of human knowledge, after the husks have been blown away by the searching blast of criticism.

The reasons for the failure, in practice, of so many deductions based upon generally-accepted theories of ore-deposition and local enrichment, have been clearly and fairly stated by R. A. F. Penrose in a recent paper entitled "Some Causes of Ore-Shoots,"* published in Economic Geology. I quote from the paper the following paragraphs:

> P. 100. "The great difficulty in classifying ore-shoots is that many totally different causes have often combined to produce any one shoot, and the evidence of some of these causes may have been much obscured or even obliterated since that time, so that the determination of just what cause has been uppermost in influence is often impossible."
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> P. 131. "The influences that may produce ore-shoots do not necessarily do so. An ore-shoot is the exception and not the rule, and even when apparently the most favorable combination of influences exists, there may be no ore-shoots. Moreover, the causes that have produced a shoot in one region may have no such effect in another region, or in another deposit in the same region, or perhaps in another place in the same ore-deposit."
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> "As a matter of fact, most of these influences seem to be practically without effect in far more cases than they have effect, and in some cases they have actually been injurious to the quantity, or quality, or both, of the ore."

Many of us used to criticize the geologists, and in particular those of the United States Geological Survey, for publishing obituaries; and to suggest that they were to blame for not being ready with an exhaustive study of a mining district until its deposits were worked out. Yet, if we cast aside the temptation to indulge in cheap sarcasm, how is the geologist to furnish a complete explanation of the facts, before the facts themselves have been laid bare? On reflection, we should admit that no final and convincing description of any mining district can ever be written, excepting as an obituary. The object of such work is to arrive at general truths which may ultimately be applied elsewhere; and in our hurry for something which the geologist cannot supply,—reliable deductions as to the nature and form of ore-bodies that the miner has not yet found,—we rush him into furnishing descriptions of phenomena which we cannot recognize when we look for them, and hazarding opinions which too often prove unfounded. Yet the fault is not so much his as ours, who expect the impossible. The result is to confuse the popular mind; to discredit Science herself, instead of the fallacies and half-truths which are delivered in the name of Science.

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* R. A. F. Penrose, Jr. Some Causes of Ore-shoots—Economic Geology, Vol. 5, p. 97 (1910).

We must learn to ask at once less, and more, of the geologist. In new and partially-opened districts, he can give us a useful and indeed essential aid,—a study of the structural geology. He can read for us the relative ages of veins and rock-formations; can assist us by collecting and correlating the data, much of which is unknown to or overlooked by the technical man who is most familiar with any given district; and can inform us what is known of ore-occurrences elsewhere where the conditions are sufficiently similar to suggest possible analogies in the deposits which result from the conditions. The less he ventures into the realm of concrete prediction, the better for his own peace of mind, and for the progressive unfolding of correct scientific conceptions.

This groundwork or outline furnished, it remains for the miner to fill in the details. It is here that the role of intelligent hypothesis, based on sound scientific conceptions, and on detailed observations drawn from practice in comparable localities, comes in. There are only two ways of conducting mining exploration. The one is essentially empirical, prospecting by shafts and levels at regular distances on a plan adopted with a view to subsequent convenience in working; or by bore-holes spaced at more or less regular intervals. This method, in its multitudious ramifications, is eminently suitable for regular veins or simple deposits. But just as we must be prepared in metallurgy to deal with increasingly complex and difficult ores, the simpler ones having been already taken care of by our predecessors, so in mining, the future belongs to the man who can find and extract the more irregular deposits; who can unravel the puzzling and intricate cases of complex faulting, and of devious ore-channels. The mere mechanical problems incident to mining are so much child's play compared with these, and I cannot but think that eventually the honor, and remuneration, attending professional work will in greater measure be regulated by its difficulties, and the quality of the faculties which are necessary to cope with and overcome them.

It has long been a favorite doctrine of mine that the problems which require to be solved are often more difficult and intricate in a small mine than in a large one, and success is often due more directly to the degree of ability applied. In each case we have to proportion our means to the attainable ends. The successful solution in the large mine is frequently only the application of a simple method on a large scale, by multiplying units. As with smelting, the inherent difficulties are often removed by merely enlarging the scale of operation. From this reflection, which I believe is indisputable, I sometimes pass to the paradox that the remuneration for the work of mine management should be fixed in inverse proportion to the size of the mine.

But to return from this digression. In the development of irregular ore-bodies, we must either adopt the same geometrical basis of exploration, which soon leads to bankruptcy, or else direct our exploration according to some working hypothesis. To "follow your ore" is an excellent maxim, when you have it; but it does not help very much when your ore is yet to be found. Hitherto, the work of hunting for ore has been left, as a rule, to the so-called "practical man." He also plans his work along the lines suggested by some hypothesis. The trouble is that, as has been pointed out by others, there is no theorist so wild or so inveterate as your "practical man;" none that rides his hobbies so hard or so far. What is needed is the trained mind, acquainted with the literature of ore-deposits in various districts; able to observe from day to day all the facts that suggest similar conditions and possibly parallel results in his own, and familiar with all the various theories of ore-deposition which are applicable to those conditions. Thus equipped, he is able to form rational hypotheses on which to base exploration, and to realize when the time has come to discard them and adopt others. In other words, the scientific miner of the future will proceed along much the same inductive lines as those which have laid the foundations and built the superstructure of all modern scientific progress; the only difference being that he cannot artificially create the conditions of each experiment, for which reason his progress must inevitably be far slower.

The detailed study of ore-deposits, with reference to their origin and distribution, requires four qualifications: First, a thorough grasp of the fundamentals of physics and chemistry; second, a wide first-hand acquaintance with other occurrences elsewhere, for the purpose of comparison; third, a close and continuous study of the deposits under consideration, for the reason that much of the evidence bearing on the genesis of the deposit is removed as rapidly as it is exposed; fourth, and most important of all, imagination, by which alone the mind can conceive tentative hypotheses of origin, to be tested by the observed facts. I have said above that I believe the complete history of any mine cannot be adequately written until the mine has been worked out. To this I would add that it cannot be done without a dependable record of its characteristics as they unfold themselves.

An ore-deposit is a palimpsest on which, throughout successive ages, various chemical and physical processes have traced their records. The most legible inscription on its surface may represent only the latest of the many influences which have contributed to the final result. By careful scrutiny we can sometimes discern, hidden perhaps in an obscure corner, traces of the half-obliterated hieroglyphics which record the earlier stages of its development.

In an examination of any such deposit, we can merely see what happens to be exposed in drifts, raises and so forth, at that particular moment. Even of these, only a small proportion, in most mines, is open for examination at any one time; and the openings themselves form only part of the total area. The visiting geologist or engineer therefore sees only a small fraction of the entire deposit, and it is natural enough that in many cases the really significant piece of evidence escapes him. The man who has the best opportunity to study the deposit is he who is familiar with it throughout the entire period when it is being worked; who sees the freshly broken face of each drift, and the developments from day to day in every working place. A relatively less degree of ability so applied may be expected to yield greater results than an occasional brief visit from an eminent scientific authority. The greatest progress in the study of ore-deposits may be looked for when these men become conversant with the fundamentals of economic geology; when the mine superintendent and the mine surveyor have been trained in the methods of the field geologist, to observe accurately and to record their observations.

Even now I do not believe for one moment that the men who do the actual work of underground mining are as unobservant or as incapable as one might suppose, judging from the comparative absence of mention of their observations in the modern literature of ore-deposits, and especially in the publications of the United States Geological Survey. I prefer to conjecture that their work has somehow failed to become adequately recognized in the publications; and that many of the luminous observations recorded are really due to the careful study of some unnamed foreman or mine superintendent who conducted the distinguished visitor through the mine. It would almost seem as if there is some convention in the United States Geological Survey which forbids its members to refer to the observations or acknowledge the assistance of any but their own colleagues, past or present.

In the future science dealing with the origin of ore-deposits, and particularly the localization of their richer portions, I believe that the work of the chronicler will be of equal dignity and importance with that of the official historian. I go further, and express the opinion that when more of our economic geologists take up the actual work of directing and planning underground mining operations, their opportunities for original observation will be improved, and the results will be careers of increased usefulness, and increased scientific progress.

So far as I am aware, the facts in connection with the localization of the workable portions of veins were first systematically observed and studied in Cornwall, and in France. A number of able observers, among who should be mentioned

W. J. Henwood, Daubrée, R. W. Fox, Capt. Chas. Thomas and Leon Moissenet, published the results of their observations and speculations throughout the middle part of the last century. The resulting literature, anticipating as it did many of the conclusions of the brilliant band of American writers who are now the acknowledged leaders in the science of economic geology, has been insufficiently studied. It is surprising to one who gives it even superficial notice, how many of the modern theories were anticipated by these writers. Their conclusions were, however, obscured by juxtaposition with other speculations which have been distanced by the general march of scientific thought, and which seem to us now as inept as some of our own will doubtless appear to succeeding generations.

The Cornish miners early appreciated most of the practical generalizations which have since been developed, such as the favorable influence of junctions, especially junctions with veins of the same age; the tendency for rich parts to occur opposite one another in parallel veins; that for workable ore-bodies to occur in those portions of a lode which are enclosed in country-rock of moderate hardness and general suitability as to fracturing and permeability; the pitch (within the lodes) of ore-bodies in stratified country in conformity with the line of intersection with the strata, etc. One rule which they enumerated, however, I wish to mention specially, because it does not correspond with my own experience, viz.: that those portions of a lode which most nearly approach the vertical are the most productive. This was explained by Moissenet and by Henwood as being due to the fact that the descent of the hanging-wall of a vein with a somewhat zigzag section would naturally contract the flatter parts and widen the steeper parts. This is reasonable enough, applied to Cornwall, where the faulting in the productive veins is nearly always normal. Most of the individual experience, however, which has colored my own conceptions of vein-phenomena has been in the western United States, where reverse faulting in veins is very common, and where the complete filling with ore of a large open fissure in stratified country, having a zigzag fracture, has not happened to form part of it. In my own observation, local flattenings of dip have been favorable places for ore, due perhaps to the opportunities such places present for the retardation of mineral solutions, and consequently the production of ore, either by deposition in a fissure or by replacement of the country.

This difference in observation, then, leads to the conclusion that we have decidedly advanced in our understanding of the subject; for instead of confining ourselves, as did Thomas and Tregaskis in Cornwall, to observations of a large number of cases, and deducing therefrom a general law which fails because the cases observed by them were confined to a single district, we have learnt to enquire the reason for each phenomenon which comes under our notice. In fact we have been compelled to reason: for mere comparison shows at once that observations are often mutually contradictory. Similarly, we have learnt that the elaborate data as to the courses of veins, which Moissenet gathered with such pains, and which Capt. Thomas considered the predominant factor influencing the productivity of lodes, have no general significance. Even my father, who to a younger and more iconoclastic mind seems to attach undue weight to the opinions of earlier students, points out that the rule formulated by Capt. Chas. Thomas is not properly applicable to the St. Agnes and St. Just districts, and goes on to say:*

> "I do not think the contrast between good and bad directions is as noticeable in the deep tin mines as it was in the comparatively shallow copper, tin and lead mines of half a century ago."

Since the classic days of Daubrée, Henwood and Moissenet many writers, including Beck, T. A. Rickard, Ransome, Lindgren and Penrose, have studied the formation of rich parts in veins; and although their conclusions give us little assistance in finding these rich parts, they enable us to form clearer and more reasonable ideas as to the reasons which in many cases have influenced their occurrence. In a discussion in Economic

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* J. H. Collins, "Observations on the West of England Mining Region" (1912) p. 123.

Geology, Vols. 3 and 4, which was initiated by Professor Irving, he draws what seems to me a useful distinction between what he calls "shoots of occurrence," thereby meaning occurrences of ore along a fissure which is completely barren of ore or gangue in its intervening portions, and "shoots of variation," which consist of high-grade areas enclosed in or separated by lode-material of lower grade. Lindgren objects to this distinction because it is not universally applicable; but I do not see that this fact lessens its practical utility. The names proposed by Irving appear to me clumsy; but the tagging with appropriate names is of relatively small importance, so long as the essential distinction between the actual ideas is borne in mind. We need a new general term for use instead of "ore-shoots," which to most people suggests one particular form or kind of ore-occurrence. Personally, I prefer to speak of an "ore-body," which conveys the idea of economic value and limitation in dimension, without suggesting any particular hypothesis of origin or special form.

In discussing Irving's contribution, Lindgren proposed a tentative genetic classification; but I see no justification for adopting a classification based on genesis while our knowledge as to the origin of ore-bodies remains so rudimentary. In preliminary discussions, however, it may be useful to consider such classifications, in order to distinguish between those classes of ore-body which we think we can explain satisfactorily, and those which we know we cannot.

The passages from Penrose which I read a short time back, which might be paralleled with similar expressions by Lindgren, and with which I entirely concur, explain why these studies as to the causation of ore-bodies seem, at first sight, to have produced little practical result. Certainly there is no royal road to the discovery of ore-bodies which do not crop out at surface. Yet the study of the subject is not without practical utility. It enables us to substitute intelligent underground prospecting for purely geometrical or empirical prospecting. Our ore-bodies are not found, as a rule, where we look for them the first time, or the second; for, as Lindgren says, the shoots "often fail to materialize where in accordance with supposition they should do so." But as the result of a great deal of hard-earned experience I do not hesitate to assert that prospecting based on intelligent hypothesis succeeds far oftener than prospecting which is blind or based on unintelligent hypothesis. Further, the trained engineer, familiar with what is known already of the causes of the localization of ore, and its occurrence under widely different conditions in many districts, has a great advantage in finding ore over the ordinary uneducated tributer.

It has frequently occurred to me that, in discussing the origin of ore-localizations containing the precious metals, and also compounds of the base metals, there has been some confusion of thought owing to failure to distinguish sufficiently between the causes which produced enrichments of gold, and those which produced ore-bodies of the base metals. The same causes which produced the one by no means necessarily produced the other. In the case of the base metals, we are dealing with appreciable quantities which can be expressed in percentages; and their ores, if sufficiently plentiful to be considered ores at all, are at once visible. With the precious metals, on the other hand, and gold in particular, we have to deal with minute proportions, one two hundred and fortieth of one per cent being a high grade ore—or quantities which, excepting for the relatively simple metallurgy of gold, could not be detected, much less worked. It is probable that other rare elements exist in common ores to at least an equal extent, the presence of which, owing to the absence of equally effective methods of assay, is never suspected. The gold in most ores, in fact, may from the standpoint of the chemist or the physicist be regarded as an insignificant and accidental impurity in the very ore-bodies which derive their economic value from its presence.

The geologist who studies this subject has usually no personal knowledge or equipment for investigating at first-hand this most important factor in the distribution of ore-values. He is dependent on the engineer or mine superintendent for information of this kind, which all engineers know is most difficult to ascertain precisely, even with close and prolonged study. How frequently it happens that, even after years of familiarity with the ores of a particular mine, with all the assistance afforded by thousands of assays, the engineer still knows little or nothing positive as to the conditions under which his precious metals occur, or the specific minerals with which they are associated. Indeed, we frequently know more, or rather imagine we know more, after the first week, than after the first year. Now, the unfortunate geologist is usually in the same position as we are after the first week: That is, he has absorbed a great many observations which have every merit, except that of being in accordance with the facts. He is necessarily dependent on the information he gets from the local operator, and the stream is no purer than its source. It is by no means true that even a man who is very familiar with a mine, necessarily knows the valuable ore by its appearance. The ores of some mines can be quite accurately graded by a person who is really familiar with them; in other cases it can never be accomplished.

I might instance the Sunuyside Extension, now known as the Gold Prince, in the San Juan, where in 1900 I opened up a consideralbe tonnage of low-grade ore, the value of which was largely in silver. The ore was of too low grade to ship in bulk, and on the other hand my tests by various milling methods, concentration and cyanidation, indicated very unsatisfactory saving of silver. I had tried hand-sorting, with discouraging results. My old friend Rasmus Hanson, however, who had previously owned the mine, and at one time extracted some profit from it, insisted that anybody who really knew the ore could distinguish at a glance what carried value and what was worthless. I therefore induced him to come up to the mine for a couple of days, and try his hand at sorting. He made three classes, first-class, second-class and reject. On sampling his three piles, it appeared that the first-class, while it ran a little higher than the other classes, was still too poor to ship; whilst his second-class ore was even lower than the reject pile.

Similarly at the Mary Murphy mine—we tried carefully picking out samples made up of fragments of various characteristic minerals, from a carload which was in course of shipment. These samples represented clean galena, zincblende, rhodonite, quartz, nearly clean pyrite and chalcopyrite, and various intermediate classes, one of which was fragments of a close-grained mixture of quartz and rhodonite, speckled or clouded with some very fine dark-colored mineral, and were selected by a tributer with many years' experience of the mine as being the richest ore. The samples on assay showed comparatively small variations in gold or silver content; but the most striking fact was that not one of them yielded as much as two-thirds the value of the entire carload. In this mine the ores are spotty in the extreme, and increasingly so in depth. While appearances may give some idea as to the probability of any sample carrying gold or silver, they are not nearly so useful as indications, as knowledge of the part of the mine from which the samples were broken.

There are other cases, as frequently occurs in Gilpin County, where we have pyrite-bearing veins, containing low values in gold and silver, which have been shattered or reopened, and re-mineralized either with copper minerals such as chalcopyrite, enargite or tetrahedrite, or with blende and galena; in either case accompanied by gold and silver in varying proportions, but always richer than the first filling of the vein. When the vein has been shattered, the result is a brecciated mass of pyrite and altered country, cemented by sulphide minerals and quartz. This condition often materially complicates the milling problems characteristic of the district, for the later and richer sulphides are usually much more friable than the original pyrite, and are less completely saved by concentration. The pyrite on the other hand is so low in grade that it does not pay its own share of the ultimate freight and smelting charges on the concentrate, and acts merely as so much gangue, reducing at once the ratio of concentration, and the grade of the concentrate. Where the vein has been reopened, the result is a definite "leader" of richer ore, which can usually be stripped and broken separately as smelting ore, leaving the balance or older part of the lode as "mill-dirt." A good share of the popular impression as to low mill-savings in this district has arisen from the expectation that the low-grade sulphides in this "mill-dirt" should yield as well as the high-grade sulphides in the smelting streak. As a matter of fact, the mill-dirt is often more worthless commercially, in proportion to the amount of sulphides it contains.

In this district it is never the case that the gold or silver is associated exclusively with any single sulphide mineral, although as a whole it is true that the gold tends to accompany the chalcopyrite or the blende, and the silver the tetrahedrite or enargite, and the galena. Even these associations of gold and silver with special sulphides are not invariable, for in some ore-bodies the chalcopyrite, which is usually the best indicator of gold, carries practically none; even in the same vein, and in close proximity to other bodies of ore which contain chalcopyrite, and are rich in gold. There is no evidence suggesting that the gold in the veins, and the accompanying sulphides, were deposited at different times. I incline to surmise that all the minerals were deposited from solutions which contained also gold and silver; that the sulphides crystallized out first, and the gold was partly precipitated with them as they formed, and partly left in solution, to be deposited later with the quartz. I suppose that the different sulphide minerals possess different degrees of precipitating power, thus accounting for the varying degrees to which the gold is found associated with them. The silver occurs partly in actual combination with the common sulphide minerals, and partly as microscopic particles of silver sulphides, or sulph-antimonides or -arsenides, in the gangue.

Another singular condition with reference to the localization of the precious metals in this district is its zonal character, which I described in a paper read ten years ago before the Institution of Mining and Metallurgy; the veins carrying an increased relative quantity of silver as they get farther from the center of the district. This condition is particularly well shown in the California and other parallel veins in the vicinity of Nevadaville. These veins at their east ends are characterized by chalcopyrite and pyrite, which towards the west are replaced by galena and zinc blende, with comparatively little pyrite. I am, however, inclined to attribute this to differences in the sources of the mineralizing solutions; something in the same nature as the "metallogenetic provinces" of De Launay, on a very small scale, rather than to differentiation in the course of deposition.

Similarly with such mines as those which I mentioned before—the Sunnyside Extension and the Mary Murphy,—the enrichment, or ore-shoots, if you will, of the precious metals and of the base metal sulphides do not coincide, excepting that the former are always enclosed in the latter. In the Mary Murphy, for instance, we have on the same level ores of identical appearance and mineralization, containing say 5 to 10 per cent. lead, 8 to 12 per cent. zinc, and one-half to one per cent. copper, which in one place will run half-an-ounce in gold, and in another place nearby a trace only. A still more striking illustration is found in the Mary vein of the same mine, where near the north end-line there is a regular shoot of vertical "pitch" (in the plane of the vein), which has been opened and proved to be continuous from surface to the 14th level, a vertical height of 800 feet. This shoot is said to have been low-grade (in gold and silver) from the 5th to the 4th level. From above the 4th level to surface it is still standing, but samples in the roof show it to be of low grade. Between the 5th and 7th levels, and down to the 9th, it is completely worked out; but the first mentioned section is said to have been very rich, and the latter comparatively poor. From the 9th to the 10th level, again, the shoot is said to have been rich in gold. Above the 11th level there was an old open stope, 20 feet high, the roof of which gave low assays. We raised through the back of this old stope to the floor of the 10th level, and after the first few feet the entire section of the raise averaged 5 ounces in gold, with absolutely no change in other respects. The 13th and 14th levels are driven through the ore-shoot, but show practically no gold values, and the same may be said of a raise which connects the 14th and 13th levels.

In fact, there is here a vertical shoot 800 feet long by 60 or 70 feet wide, which is practically uniform throughout in dimensions, mineralogical character and appearance. Yet when we consider the precious-metal content, on which the commercial value of the ore-body mainly depends, we find that there is an alternation of rich and poor bands, which we are so far absolutely unable to account for. There are apparently no feeders coming in from the walls, to enrich the vein; and the granite country is uniform from top to bottom.

There are other cases in this mine, between the 7th and 14th levels, of fairly definite ore-shoots, with their longer axes vertical, containing quartz and rhodonite with zinc and lead sulphides, which usually carry very low values in gold and silver; but in which there are occasional patches of high-grade ore, occurring without any apparent cause. The precious metals in this part of the mine might be described as occurring in irregular patches, the only uniform rule being that the enrichments are always enclosed in the zinc-lead sulphide ore-shoots.

My personal experience leads me to the conclusion that the distribution in veins of gold is characteristically more irregular than that of the base-metal sulphides. The extent to which this is true is sometimes not realized, because of insufficent sampling, and because in actual stoping the ore gets mixed enough to "average up." But in some large veins, like those of San Juan County, gold has a marked tendency to occur in sporadic nests, suggesting some sort of segregating process from the solutions which supposedly deposited the quartz. I am unable to hazard even a hypothetical explanation of this tendency, unless it is in connection with the recent experiments of Hatschek and Simon* on the precipitation of gold from silica gels, which suggest the possibility of such a precipitation in a gel taking the form either of layers or irregular segregations. It is difficult to comprehend such irregularities on any supposition of the gradual deposition from solutions which are trickling slowly or impounded.

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* Hatschek and Simon. Gels in relation to Ore Deposition. Bulletin No. 91. Institution of Mining and Metallurgy. April 11, 1912.

As an aid to the discovery of ore-shoots, nothing is so important as persistent sampling. By that I do not mean the systematic sampling employed to delimit and ascertain the value of ore-bodies, the methods employed in which have been thoroughly worked out and described for several years past. I mean rather the kind of sampling which is employed —only not nearly so thoroughly as it should be—by the tributer in search of a "pitch." This kind of sampling is directed more to find *where* values are, than *what* they are: it tests every separate stringer, regardless of size, and every novel vein-material, however small in quantity. Its use reminds one of the children's game of "hide and seek," in that directly you get a good assay you may be "warm," for it proves that solutions carrying high values have been at work in that vicinity, and it is time to hunt for their channels. More and more, experience teaches me that this is the essential factor in prospecting. The mineralization being of the right character, there is always a fair chance of finding some place where its effects have been concentrated sufficiently to create commercial ore-bodies. On the other hand, I have learnt to distrust the veins, however large or "well-defined," which show no evidence somewhere or other of mineralization by solutions which were capable of depositing a workable grade of ore. Nearly every mining district contains plenty of such, which have every requisite for making good mines, excepting pay ore. There was a time when a fine-appearing vein appealed to me in itself; and I recollect that at one time I used to suppose that in choosing a place to prospect, it was necessary to select "a fine large generous vein," so that if an ore-body occurred in it, there would be plenty of space for a large one. I have grown out of all that. Granted the right kind of mineralizing solution, and a fissure, however small, the elements are there already. At some point shattering or faulting will have made spaces enough in which to deposit ore; or, if not, the mineralizers can usually eat out their own receptacle.

I might illustrate this by a concrete case, taken from the Druid mine, in Gilpin County. The main vein of the Druid property is the Searle, a wide soft fault-fissure which can be traced for several miles, and is probably the longest continuous proved vein in the district. It is known elsewhere by other names, such as the Frontenac, Aduddel and Kokomo; and about 4,000 feet of its length is contained in the Druid property. The main output of the mine, however, has been furnished, not by the Searle, but by irregular fissures lying to the north of, and roughly parallel to it. These fissures are probably older, and seem at one place to be faulted by the Searle on the dip, and at another place both on the strike and dip. They are mere cracks, so irregular and so indistinct in places as to be indistinguishable, especially when the rock is freshly broken. One may be within three or four feet of a high-grade ore-body, an equal number of feet in width, and yet be unable to distinguish the crack which represents the fissure. In one place we crosscut the Middle vein, one side of the crosscut showing three feet of rich ore in the bottom, and a mere but distinct crack above it. The other side showed nothing, not the smallest continuous seam can be distinguished even now, six months later; yet I am sure the seam goes through in the same direction, for we have a level which follows the vein all along only fifty feet above, and on the level first mentioned, a stope comes to within 45 feet of the wall of the crosscut.

The same crosscut, a short distance further in, passed through the North vein, without our being able to distinguish it then or later.. Yet a rich stope lay only fifteen feet above, and diverging branches of the continuation downwards of the same stope were later found on each side of the crosscut, within a few feet of its walls.

The ore, where it occurs, is a replacement of the schistose or gneissoid country, which here lies nearly flat, dipping on an average ten or fifteen degrees from the horizontal. The form, as shown by the worked-out spaces, is that of irregular pipes, from ten to thirty feet long along the course of the fissure, and one to ten feet thick, the longest axis being usually vertical. Between the pipes the veins are absolutely barren, so that these represent Irving's "shoots of occurrence." The pipes, and the mineralization, appear sometimes to be localized by intersecting fissures which are even more indistinct, being only visible in a few places where the mineralization has fingered out along them.

The strangest thing about these ore-bodies—for they are worthy of being considered as commercial ore-bodies, the average value of the material broken in them being fully $40.00 per ton in gold and silver—is the details of their structure. The mineralization is even more erratic than is indicated by the shapes of the worked-out stopes. The ore is a partial replacement by galena, quartz and pyrite, with a little chalcopyrite and a black amorphous mineral which is possibly chalcocite, of layers in the schist, and especially the more micaceous layers. At times a stope will appear to end absolutely against a layer of unmineralized country, beyond which the country may be completely replaced with ore for a thickness of six or ten feet.

The ore is best in the schist formation. Lower down, the vein cuts through pegmatite, where the mineralization is much more coarsely crystallized and more irregular. One ore-shoot in its upper course passes through a dike of porphyry, and here the ore is a narrow solid streak of pyrite. Immediately above this are two "rolls" of ore, rhomboidal in section, which run out horizontally for forty feet. A little farther up again this particular ore-shoot crossed, and was faulted by the Searle.

What happens to these particular ore-bodies in depth is not yet certainly known. Two of them which have been followed down to the bottom appear to merge into a vein of ordinary pyritous low-grade ore.

As will be readily understood, if a fault occurs at a barren place in the vein it is almost impossible to find the vein beyond. Almost the only chance is to pursue exactly the same method which is sometimes effective in finding such ore-bodies originally—to crosscut through the locality where the vein should be, and if a seam is found that gives any encouragement on assay, to follow it by drift and raise. Even when stoping or sinking a winze on an ore-body of this character, it is difficult to follow; when it is once lost completely, the task of relocating it becomes almost impossible. We have found pyritous ore-bodies of similar form, but contained in a more definite vein, occurring below the ore-bodies first described, in such a way as to suggest the possibility that they really constitute their extensions in depth. In this case we should assume that the difference in character of mineralization, as well as the difference in the vein itself, was due to the nature of the country. In the denser gneiss, the vein according to this hypothesis may have been clean-cut, and have remained more or less open; in the more yielding schist, it dwindled to a mere irregular crack. But owing to greater solubility of the micaceous layers of the schist, the solutions were able to thoroughly replace them, forming ore-bodies of higher grade. The lower tenor of the ore in the gneiss is partly due to its admixture there with barren pyrite, which cannot be effectively removed in sorting, as it breaks into fines. The ore in the schist, on the other hand, has nothing but absolutely barren waste rock broken with it, and this can be more effectively sorted out.

So far as I know, this is the only case in Gilpin County of an ore-body being better in the mica-schist than in the harder gneiss or granite. The reason for this is doubtless that the veins in the former usually lose their identity. I suspect that deposits such as these along the North and Middle veins in the Druid are the result of an earlier and quite different period of mineralization, than those of the better-known veins. In the Druid, indeed, we have evidence of three distinct periods; first, the ore-bodies of the North vein type, which I have just described; second, the Searle vein itself, which faults the former; and third, the period of reopening and brecciation of the Searle vein, as a result of which most, if not all, of the economic ore which it contains was introduced.

When I first began to outline my subject for this address, I intended to give some account of the methods, by hypothesis and experiment, or trial and error, as some will disrespectfully prefer to call it, by which I have endeavored to systematize in practice the search for irregular ore-bodies in fissure veins. Such experiences of course include far more cases of failure than of success. Yet I believe this to be the only rational means of searching, and that in the long run its results are far more satisfactory than the ordinary haphazard methods employed. This address has, however, already gone beyond the limits of time which I set for myself, and the concrete examples must stay over for another occasion; by which time perhaps the number of interesting illustrations which I have to offer will have been increased.

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RADIOACTIVITY OF THE MINERAL SPRINGS OF MANITOU, COLORADO.*

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(Read at the Meeting of the Society, November 2, 1912)

It is perhaps surprising that as yet no systematic exploration of the radioactive properties of Colorado waters has been completed. So far as I am informed the only published work is that of Dr. W. P. Headden, on the Doughty Springs of Delta County,† and Professor Wolcott of the School of mines,‡ who in 1904 did some testing on water from Glenwood Springs. The present work originally contemplated a complete examination of the Manitou group of springs. It is a matter of regret to the writer that these plans could not have been carried out in full, and the present paper is presented in the hope that ere long some one may complete the task.

The Manitou springs have since Indian days, been famous for their medicinal properties. Such properties have been ascribed to the minerals and gases present in solution, and latterly to their radioactive character. That both causes are potent is likely, though it would doubtless be more difficult to place a quantitative estimate upon the latter than upon the former.

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*In the spring of 1904 work was begun looking to a study of the numerous springs of Manitou, Colorado, relative to their radioactivity. Subsequent removal from the state made the completion of the work impossible. It is thought that the publication of these preliminary results may prove of interest to some future work, and they are set forth with a full realization of their incomplete character.

†Proc. Colo. Sci. Soc. Vol. VIII, 1905.

‡Appendix Biennial Report, Colorado School of Mines, 1904.

GEOLOGY OF THE MANITOU REGION.

The geology of the region is one of unusual interest and much pains has been exercised in seeking to understand the whole problem, including in this the source of the abundant supply of mineral water surcharged with CO_2.

Professor Strieby of Colorado College has so thoroughly expounded the matter from the viewpoint of Geology that I cannot do better than to quote at length from his paper (Colorado College Studies, 1894).

"Manitou lies in a mountain gulch or valley at the base of Pike's Peak, and just at the entrance to the Ute Pass. . . . . The stream . . . . . obtained the name "Fontaine qui bouille" from the bubbling or boiling springs on its banks at Manitou. On the south and west . . . . . rise the granite slopes of Pike's Peak, while to the north are piled up the huge masses of stratified rock which flank the other side of the valley. Thus Manitou lies at the junction of the old archaean rocks, with more recent sedimentary formations. Just west of Manitou, however, the limestone beds are found for a short distance on both sides of the Ute Pass. The archaean rocks at Manitou consist almost exclusively of highly feldspathic red granite which disintegrates very readily under atmospheric agencies. Farther up the Pass are found patches of syenitic gray granites containing soda feldspars. There are no igneous rocks in this neighborhood save a few narrow dikes, and on the south slope of Pike's Peak, about two miles from the summit, one exposure of phonolite, but not many miles distant at Cripple Creek, large areas of eruptive rocks are exposed to view. A number of rock slips or faults in the granite are to be seen in the neighborhood of the Peak.

"At Manitou and to the northwest, only the paleozoic series of sedimentary beds are exposed, e. g., silurian, carboniferous, and juratriasic, and these are mainly represented by limestones and sandstones. The granite slopes of the Front Range, which extend in a generally north and south line, are depressed in a sort of recess or bay at Manitou and to the northward, and these older sedimentary beds rest upon them, and outcrop in their regular order, showing themselves for several miles up the Ute Pass. To the northwest of the Ute Pass and continuing in the same direction, extends a long, narrow strip of the same series of sedimentary formations. Probably these two areas were once continuous and have since been separated by erosion. At the lower end of the latter, or Manitou Park, area, a prominent fault having a slip of three or four hundred feet follows the junction of the granite with the southern side of the sedimentary beds,* and at Manitou, near the Rainbow Falls, there is also a fault with a slip of twenty feet or more, which takes about the same direction. It is probable that these faults form a continuous fissure over the short interval between the two areas, and it is quite possible that the influence of this fissure or slip determined the course of the stream which cut the Ute Pass so deeply in the rocks. From the prevailingly slight dip of the strata it is probable that the sedimentary beds at Manitou do not extend to very great depths beneath the surface, and the same observation applies also to those at Manitou Park. At Manitou the general inclination of the beds is to the southeast, though there are several folds which steeply incline some portions of them just west of the city.

"There are, however, in the vicinity of the springs at Manitou, a couple of small flexures of strata, indicated mainly by rock exposures on the north side of the valley which should be noticed. They run transversely across the valley, and may be described as being only more abrupt or sudden inclinations of the southeastwardly dipping strata. It is at the crests of these low folds that the springs appear. The oldest limestones are very silicious, and in places just west of Manitou where they are shattered and bent, often contain cavities filled with argillaceous red oxide of iron. The "Caverns" so much visited at Manitou occur in the limestone, and show the results of a former great chemical activity at that point. When first discovered, very considerable beds of the same ferruginous matter covered the floors and filled some of the passageways of the caves. The springs are found at three points in the valley, and these places are at the apices of a triangle roughly equilateral. The group including the Navajo, Manitou, Cheyenne and Shoshone, which lies in the center of the town, and forms the eastern end of the triangle, has the largest flow of water and gas. The eastern of the two transverse rock flexures occurs at this point. West of this group the valley widens and divides, and the Ute Iron spring is found in Engleman's Canon, a short distance above its mouth, and almost in the granite. The third position, that of the Hiawatha group, is in the line of the valley, near the limestone rocks, and not far below the entrance to the Ute Pass. It is said by old residents that the largest spring was not many years ago found at this place, but that it was deeply covered and quite obliterated by deposits of gravel brought down the Pass during a severe freshet. In the neighborhood of each group of springs the gravel and wash has been cemented by a tufaceous substance deposited from the waters and called locally "soda-rock." The Navajo group and the Ute Iron spring are near to the line of contact of the granite with the sedimentary beds; the Hiawatha group is near the line of the Ute Pass fault.

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*See the Pike's Peak Folio, edition of 1892, U. S. Geological Survey.

In all cases the springs lie close to the streams, and in the creek bed near some of them, numerous small vents are shown by rising bubbles of gas."

Again referring to the temperature of the water, Professor Strieby says (p. 19) :

"The temperature of the Navajo and Manitou springs was tested on two or three occasions and found to be about 15°C. In July, 1894, it was also the same. On December 31, 1894, after five days of quite cold weather (the thermometer registering nightly —18°C. or lower), and again on January 10, 1895, after a continuous period of cold weather, the temperature of several of the springs was tested, and samples of water from some of them also taken. The temperatures observed, and the residues obtained by evaporation of the samples of water, are given in the subjoined table. The residues are given in grains per gallon.

Date of Test	*Name of Spring*					
	Navajo	*Manitou*	*Ute Iron*	*Ute Chief*	*Hiawatha*	*Hiawatha No. 2*
December 31						
Temperatures C.	14·5+	14·5	12·0	11·0	†11·5+	11·5−
Residues	178·40	....	*109·52	....	119·16	51·10
January 10						
Temperatures C.	14·5+	14·5−	7·0	....	†12·0	11·0
Residues	177·57	176·12	113·66	....	117·86	50·85

"No thermal springs are found in this vicinity other than those at Manitou."

In regard to the supply of CO_2 gas Professor Strieby says (pp. 19 and 20) :

"The gas emitted from all of these springs is pure carbondioxide. The quantity given off from the different springs is quite unlike, varying from a few hundred cubic centimetres per hour to three or four hundred litres or more in the Navajo and Cheyenne. The flow from each spring is, generally, during the greater part of the year, very uniform in quantity, though it is said that after heavy rains or when snow is melting the quantity given off is increased. This increase may arise from greater hydrostatic pressure of the swollen stream upon small vents in the creek bed and unseen vents along the banks near the springs, thus forcing more gas through the main channel. The foreman of the bottling department of the Manitou Mineral Water Company's plant reports that a diminution of the flow of both water and gas occurs in the Navajo group of springs during the coldest weather of winter. It is to be observed that the spring waters never become turbid or roily after storms and freshets, although the surface streams are especially affected in this way. One of the springs of the Hiawatha group (the covered one), is slightly turbid from insoluble salts which probably result from reactions occurring in close proximity to the spring. Some of the spring waters on standing, quickly deposit a precipitate, while others, even from the same group of springs, remain clear for a much longer period. Considerable pressure is developed by the escaping gas when the waters are immediately bottled and hermetically sealed as soon as drawn from the springs. Large glass vessels are apt to be burst by the pressure of gas if filled quite full before sealing."

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*A small precipitate of an iron compound had formed and settled before the analysis was begun—the result is therefore a little low.

†The Hiawatha spring is covered with an iron cap, cemented to the curbing, and the water tested on December 31 was obtained from the overflow and caught in a gallon measure, and as the vessel was cold the temperature obtained was probably too low. On January 10 the thermometer was held in the water escaping from the overflow pipe. This overflow pipe is buried under four or five feet of gravel and is some twenty or thirty feet in length.

Summing up this part of his paper Professor Strieby says (pp. 20-22) :

"1. All the springs hold the same salts in solution, a fact which seems to point to a common origin.

"2. The waters of the Navajo and Manitou springs are almost identical in mineral contents, while the Ute Iron spring contains a much smaller quantity of dissolved salts. There is also a difference in the weight of the residues from the Hiawatha springs. It is very probable that percolating waters from the streams or from local seepage channels, make their way into the springs—such influx being greater in some springs and smaller in others. In the Ute Iron spring calcium and magnesium are low, and silica, chlorine, iron, sulphuric-anhydride, soda and potash relatively high. The proximity of this spring to the silicate rocks on the south, and to the very broken silicious silurian limestone and cambrian quartzites on the north and west, suggest reasons for a possible change in this spring water, on the supposition that its main source is the same as that yielding the waters of the other groups.

"3. The presence of so large quantities of the bicarbonates of calcium and magnesium points to a prolonged contact of the waters with the limestones.

"4. The almost total absence of iron salts indicates either a source quite free from ferruginous minerals, or more probably the oxidation of dissolved iron and its previous precipitation as hydrated sesquioxide by the carbonated alkaline matters with which its comes in contact as the waters move toward the springs.

"5. The high percentage of chlorides may be derived from the silurian rocks or with less probability from the more distant juratriasic beds, since no saline deposits in them are known in this vicinity.

"6. The large percentage of sodium bicarbonate probably indicates an origin among silicate rocks, whence the soda (and potash), may come as carbonates formed by the decomposition of the rocks by atmospheric waters containing carbonic acid, or as alkaline silicates, which react upon the limestones (calcium carbonate), before reaching the surface.

"7. The sulphates may come from unseen gypsum beds such as are found two or three miles away, and lower down the Fountain creek, but it is more probable that they come in greater part at least from the oxidation of sulphides in granites, igneous rocks or even sedimentary beds. The oxidation of ferrous sulphate, such as was described as occurring in the Ute Pass, gives rise to sulphuric acid, and by subsequent reaction with carbonates to sulphates of the alkalies. The ferruginous deposits in the broken silurian limestone indicate such a reaction.

"8. The concentration of the solutions—that is, the large quantity of mineral matters contained in the spring waters, comes evidently from prolonged contact with rocks, such as would arise from percolation, and probably also from an increased solvent power of the water, due to heat or pressure, both combined.

"9. The difference in temperature of the several springs is remarkable as showing that either the waters come from different sources, or if coming from the same source have been cooled in an unequal degree by passing through diverse strata, or through the influx of cooler foreign waters. It was assumed under (2) above that the most probable view was that the same water is made to vary its content of dissolved mineral matters by the admixture of other waters; and the variation in temperature between the springs will be found on inspection of the table above to be in striking harmony with this supposition. The temperature in general is lower when the mineral content is lower, but it should be remembered that the inflowing foreign waters may also pass through strata so deeply buried as to be much warmer than mere surface waters.

"10. The variation of the springs between summer and winter, in their contents of mineral matters dissolved, in the quantity of water flowing from them, and in the volume of gas yielded, together with the remarkable uniformity of temperature throughout the year in some of them, are evidently significant phenomena. The causes producing them will be discussed in a subsequent paragraph."

From these and other considerations contained in this admirable paper Professor Strieby formulates the following theory as to the source of the Manitou mineral water (pp. 26-29):

"Reference has already been made to the faults and rock-slips at Manitou, and to the probability of the presence of an extensive and profound rock-fissure extending from Manitou continuously along the general line of the Ute Pass up into Manitou Park. In view of the presence of an extensive outflow of igneous rocks not many miles distant at Cripple Creek, and of an outcrop of phonolite nearer still on the south side of Pike's Peak, it is altogether likely that a deep fissure such as that at Manitou, if not in some way connected with those disturbances and the loss of interior liquid matter under this region, yet penetrates to depths strongly affected by these heated zones. If a fissure occurs at Manitou which penetrates the earth's crust sufficiently to reach highly heated rocks, the natural action observed in fissure-vein filling will be very actively induced, and highly mineralized solutions will result as before explained. And if further the fissure at Manitou extends to Manitou Park or communicates with fissures of the Cripple Creek district or with those in some other elevated region, the waters which everywhere find exit in such rock crevices, would, in seeking their level, according to physical laws, naturally emerge at the lower point where the springs are found. Heated waters, or waters even slightly heated, on coming into contact with the superincumbent limestones of Manitou would promptly set up chemical reactions caused by the presence of soluble matters such as the silicates of the alkalies and other metals, silicic acid, sulphides, sulphates, etc., derived from the heated rocks. The reactions which would take place need only be generally indicated here since they are not peculiar to this theory. Alkaline silicates would change to carbonates; alkaline bicarbonates, in so far as these reactions were possible, to sulphates, or,—if chlorine combinations of lime and magnesia exist in the silurian limestone—to chlorides, in both cases—at even a very moderately elevated temperature—with the evolution of carbon dioxide; iron salts would first become carbonates and then peroxidize, setting carbon dioxide free and forming a ferruginous precipitate. If the waters were only slightly hot, silicic acid would form insoluble calcium silicate with the liberation of carbon dioxide. In the case of hot waters the basic carbonates of magnesia and probably also of calcium would be formed instead of normal or acid salts by reactions of the salts of the alkalies, etc. These, with other known and possible reactions, account for the generation of the gas. The salts contained in the spring waters may also be fairly explained in part by these reactions, and in part by reactions produced, and other salts introduced, through the accession of seepage waters in the passage to the springs. The concentration of solutions, or the high percentage of salts in the water, is well explained by this derivation. A large fissure like the one assumed to exist at Manitou must receive meteoric waters by seepage along its whole course, and such additions bring with them each their small quantity of dissolved salts. The waters which emerge from the fissure at or above Manitou must also be considerably changed in mineral contents by the accession of seepage waters from the local rocks, and these changes are probably greater at some points than at others. The difference in temperature between the various springs, and also their difference in mineral matters dissolved in the water, may thus be credibly explained. The surface waters do not readily make their way through the "soda-rock" into the springs and hence the springs do not become roily, and the temperature of the water remains quite constant, retaining still enough heat to be designated as 'thermal' in the U. S. Government Reports.

"The coincidence between the diminution of the salts and that of the water and gas during the coldest winter months, probably arises in this manner. The feeders of this fissure-flow are in large part the seams and cleavage cracks in the rocks adjacent to the main fault or its branches, and they in turn derive their supply from the surface waters which percolate downward. In the very cold weather the seepage waters —as is well known in mining regions at high elevations—are greatly diminished, being held in check by frost, so that the supply is lessened in the main fault. In like manner the slopes of the Ute Pass and the neighboring hills which may be supposed to furnish the seepage waters of the sedimentary beds at Manitou are restraining (by frost), their quota of the supply of the springs. Especially would this be true if, as appears probable, the more elevated and comparatively shaded south side of the Pass furnishes the bulk of the seepage waters which make their way to the springs. Under these conditions the temperature of the springs would not generally greatly vary in summer or winter, since the colder surface waters of the latter season which mingle with the decreased fissure-waters would also be much diminished in volume. With the decrease in water would come a decrease in salts, and so also of the gas produced by the reactions previously outlined.

"The salts coming from the assumed fissure beneath the limestones naturally tend to follow the seams and bedding planes of the stratified rocks and thus to make their way down the easterly slopes without coming to the surface. The resistance to this flow resulting from friction and perhaps from sharp folds and faults east of Manitou, causes the waters to force an exit through the broken and folded strata at the western side of the city. The two small flexes of surface rock before mentioned appear to give in their crevices the opportunity for a final escape to the surface of the water and gas.

"All the circumstances, therefore, connected with the position and flow of the springs, and the mineral contents of the water, etc., etc., seem to be consistent with, if they do not favor this explanation.

"Briefly, then, the theory advanced of the origin of the natural gas at Manitou may thus be summarized: Water percolating through silicate rocks and becoming highly mineralized under favorable conditions of temperature and pressure, makes its way through cracks and profound rock-fissures by the action of gravity and the ascensional power imparted by heat, to the limestones west and north of Manitou. It is here increased in volume and in dissolved salts by the numerous additions of seepage waters from the local rocks, and also lowered in temperature at the points where these influxes occur. By chemical reactions some of the dissolved salts are changed, and the carbon dioxide originally held (almost entirely), by the limestones is liberated from that combination, but dissolved in the water on account of the great hydrostatic pressure. As the waters rise through the irregular channels enlarged from cracks and seams, the pressure decreases, and more and more of the dissolved gas escapes from the water, until at last when the surface is reached at the various springs the gas emerges with the rythmic flow due to the irregularities in the channels of exit."

CHEMICAL ANALYSIS OF WATER FROM THE MANITOU SPRINGS.

Next to the geological problem and associated with it is that of the chemical composition of the water from the various springs. Of these springs there are three groups more or less separated from each other.

I. The first is by far the best known, being located in the center of the town and having the greatest popularity as a drinking water. Four of these springs have been given names as follows: Manitou, Navajo, Cheyenne and Shoshone.

II. The Iron springs, located a short distance up Engleman canon, not far from the Cog Road depot. Here are found Ute-Iron, Ouray and Little Chief Springs.

III. The third group is located a short distance up Ute pass. The two main springs are Hiawatha and Ute Soda springs.

The following tables give analyses of representative springs of each group. They are compiled, table A from the literature furnished by the proprietors of the several groups, table B from the report of the U. S. Geological Survey and table C from the Chemical department of Colorado College.

TABLE A.

			Grains per pint			
Constituents	*I*	*II*	*III*	*IV*	*V*	*VI*
Carbonate of Calcium	8·635	8·667	3·200	2·250	4·750	6·023
Carbonate of Iron			3·700	3·500	1·500	0·031
Carbonate of Lithium	0·088	0·077	1·250	1·500	1·500	0·092
Carbonate of Magnesium	2·085	2·005	1·200	1·125	1·250	0·092
Carbonate of Sodium	5·083	5·326	4·125	4·000	1·100	4·271
Carbonate of Strontium						trace
Chloride of Potassium						0·213
Chloride of Sodium	2·993	2·974	3·100	3·250	3·750	
Oxide of Iron	0·003	0·003				
Sulphate of Calcium						0·214
Sulphate of Magnesium						1·123
Sulphate of Potassium	1·336	1·244	1·100	1·125	1·000	trace
Sulphate of Sodium	1·268	1·367	2·200	2·125	3·000	
Alumina	0·009	0·013				
Silica	0·312	0·308	1·000	1·000	1·000	0·134
Totals	21·812	21·984	20·875	20·125	18·850	12·193

I, Manitou Spring; II, Navajo Spring; III, Ute Iron Spring; IV, Ouray Spring; V, Little Chief Spring; VI, Hiawatha Spring.

TABLE B.

			Parts in 100,000			
Constituents	*I*	*II*	*III*	*IV*	*V*	*VI*
Calcium Carbonate	111·00	129·40	108·50	59·04	75·20	40·00
Iron Carbonate	trace	.....	......	5·78	1·80	1·40
Lithium Carbonate	0·21	0·24	trace	trace	trace	trace
Magnesium	20·51	31·66	......	14·56	13·01	6·10
Sodium Carbonate	52·26	124·69	88·80	59·34	15·16	23·82
Sodium Chloride	40·95	39·78	42·12	31·59	47·97	13·93
Potassium Sulphate	13·35	16·21	5·12	7·01	6·24	trace
Sodium Sulphate	19·71	18·42	37·08	30·86	51·88	12·24
Silica	2·01	1·47	trace	2·69	2·22	trace
Totals	260·00	261·87	281·62	210·87	213·48	97·49

I, Manitou Spring; II, Navajo Spring; III, Shoshone Spring; IV, Ute Iron Spring; V, Little Chief Spring; VI, Ute Soda Spring.

Table C done by Orrie W. Stewart of Colorado College is probably the most careful analysis of Manitou water yet presented. The water was furnished by the Manitou Mineral Springs Co. and came from the Navajo and Cheyenne springs.

TABLE C. Analysis of Manitou Soda Water.

Constituents as Determined	*Parts per Million*	*Dec. 18, 1911* *Grains per U. S Gallon*
Silica	46·40	2·706
Sulphuric Acid (SO_4)	208·40	12·157
Bicarbonic Acid (HCO_3)	2725·10	158·968
Chlorine	236·60	13·802
Iron	·60	·035
Alumina	·50	·029
Manganese	3·10	·180
Calcium	465·60	27·160
Magnesium	80·40	4·690
Potassium	78·60	4·585
Sodium	545·60	31·827
Lithium	·93	·054
Oxygen to form Mn_3O_4	1·20	·070
	4393·03	256·263
Total Solids by Evaporation	2993·00	174·595

Compounds as they probably exist in solution in the water	*Parts per Million*	*Grains per U. S. Gallon*
Lithium Chloride	5·62	·327
Potassium Chloride	149·70	8·732
Sodium Chloride	265·30	15·476
Sodium Sulphate	308·40	17·990
Sodium Bicarbonate	1243·70	72·548
Magnesium Bicarbonate	484·30	28·251
Calcium Bicarbonate	1882·90	109·838
Ferrous Bicarbonate	1·90	·110
Alumina	·50	·029
Manganous-manganic Oxide (Mn_3O_4)	4·30	·250
Silica	46·40	2·706
	4393·02	256·257

RADIOACTIVITY.

Professor E. R. Wolcott reports as follows on his tests on the radioactivity of Colorado waters:*

> "In Colorado are found many radioactive minerals and also many springs which are radioactive. In April of last year the author made an examination of the Yampah spring at Glenwood Springs. . . . . The radioactivity of the natural gas is very marked. Some of the spring water that was obtained at Glenwood Springs last April was boiled in October, and the gases thus obtained were tested and found to be radioactive. . . . . The deposits around the spring were tested and found to be somewhat radioactive.
>
> "In conjunction with Professor Shedd of Colorado College, the author examined the Navajo spring at Manitou and found that it gave off a radioactive gas, but this work is not yet completed. . . . ."

The tests to be described in the present paper are a continuation of the work mentioned by Professor Wolcott, although he was at no time able to be present or to take part in the experiments.

Apparatus.—The apparatus consisted of a gold-leaf electroscope slightly modified from the one used by Professor Wolcott at Glenwood Springs. It is shown in Fig. 1.

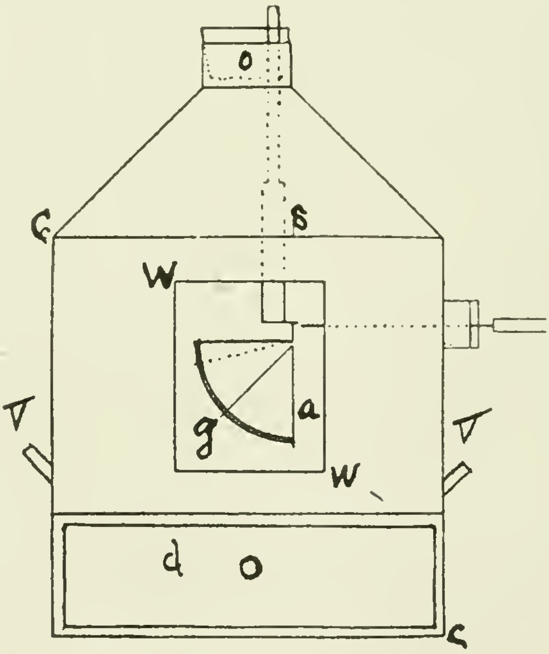

Fig. 1.

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*Biennial Report of the Colorado School of Mines, 1904.

In Fig. 1 *c c* is a tin case with two windows *w w*, on opposite sides. These windows are covered with mica on each of which an arc of 90° has been drawn. A brass strip *a* is fastened to a sealing-wax rod *s* which passes through the cork *o*. To the strip *a* is gummed a narrow strip of gold-leaf *g* in such a manner that when charged it will swing out over the angular scale. At one side of the case and passing through it by means of an insulating bushing, is a metal rod having a sealing-wax end. If this rod be pushed in it comes into contact with the brass strip *a*. If now a charged glass or ebony rod be touched to the metal rod the gold-leaf becomes charged. By now withdrawing the metal rod, by means of the sealing-wax head, the gold-leaf is completely isolated within the tin case. Adjustments can readily be made so as to have the hinge of the gold-leaf lie accurately at the center of the arc. Readings are then taken by setting the eye so that the arc of the near scale is tangent to the arc of the far scale at the point where the gold-leaf crosses it. Readings to 1° may be made with confidence.

Theory and Formulae.—When charged the gold-leaf is seen always to stand out in a straight line, at whatever angle it may happen to make on the scale. From this fact the following is developed. In Fig. 2 *og* is the gold-leaf, and *a* the brass plate to which it is attached.

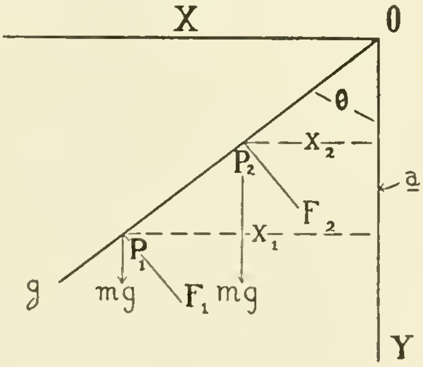


Fig. 2.

If we consider two points P_1 P_2 on the gold-leaf, the force of gravity on a narrow transverse strip of mass m is $m.g$, where g is the acceleration of gravity. If F be the intensity of the electrical field and dQ the electrical charge on the strip m then $F.dQ$ is the electrical force acting on the strip. Since the gold-leaf is an equipotential surface *F* is normal to *og*. Also, since the gold-leaf is in equilibrium it follows that the moment of the electrical force and the moment of the force of gravity about the point *O* are equal. This leads to the equations:

$$m.g.x_1=F_1.(dQ)_1.op_1, \text{ and } m.g.x_2=F_2.(dQ)_2.op_2.$$

If the first equation be divided by the second we get the expression

$x_1/x_2=F_1.(dQ)_1op_1/F_2.(dQ)_2op_2$: But $x_1/x_2=op_1/op_2$ and therefore

$$F_1.(dQ)_1/F_2.(dQ)_2=1\text{: from which } F_1.(dQ)_1=F_2.(dQ)_2.$$

From this it is seen that the electrical force on the gold-leaf is everywhere uniform. The most probable conclusion to be drawn is that the force *F* varies inversely with the distance, and the charge *dQ* varies directly with the distance from the plate *a*, the product $F.(dQ)$ remaining constant.

On the hypothesis that the charge varies directly with the distance we may write,

$$dQ=K.op_1=Kl, \text{ where K is a constant.}$$

Also the charge dQ will be equal to,

$dQ=\sigma.b.dl$, where σ is the surface density of charge, *b* the width of the gold-leaf and *dl* the width of the strip carrying the charge *dQ*. The surface density of charge will follow the same law as does the charge and therefore we may write $\sigma=\sigma_0.l$, and hence

$$dQ=\sigma_0.b.ldl.$$

The charge on the whole leaf is,

$$Q=\sigma_0.b\int_0^L ldl$$
$$=\tfrac{1}{2}(\sigma_0.b.L^2).$$

Considering the turning moment $T\epsilon$ of this charge *Q* about the point *O* we get

$$dT\epsilon=l.F.dQ, \text{ and since } F:1/l$$
$$=F_0dQ\text{; from which we get}$$
$$T\epsilon=F_0Q$$

In a similar, though simpler, manner the turning moment of gravity is found to be

$$T_g=M.g.\tfrac{1}{2}.L.\sin\theta.$$

Now since the gold-leaf is in equilibrium the turning moment due to the electrical action and that due to gravity equal each other; therefore we may write,

$QF_o/=\tfrac{1}{2}.M.g.L.\sin\theta$, from which we get

$$Q=\tfrac{1}{2}\tfrac{L}{F_o}M.g.\sin\theta$$

Finally $dQ/dt=\tfrac{1}{2}\tfrac{L}{F_o}M.g.\cos\theta\ (d\theta/dt)$ . . . . (1)

This discussion is necessarily brief and inadequate; the essential conclusion, however, that dQ/dt varies as function $(\theta).d\theta/dt$, I think is correct.

Let us now turn our attention to a consideration of radioactive substances: The radioactivity of a substance is due to the spontaneous disintegration of its atoms, resulting in a liberation of both positive and negative electrons. It is the presence of these free charges of electricity that make it possible to observe the phenomenon, for if a charged electroscope be present it will lose its charge at a rate which depends upon the radioactive substance. The radioactivity may be regarded as proportional to the surface exposed, and to be indicated by the *rate* at which the electroscope loses its charge when the sample is in its proximity. When minerals are tested the sample is powdered and placed in the slide *d*, Fig. 1, on a watch-glass and over a circle of known size. The rate of fall of the gold-leaf produced by the sample and that produced by a standard —such as Uranium—are then compared.

In the case of a gas the vent V, Fig. 1, is used as an inlet for the gas and the flow adjusted. In this case it was first planned to measure the rate of flow of the gas, but it was found that the rate of fall of the gold-leaf was independent of the rate of flow of the gas. It thus seemed clear that the bottom of the electroscope case was covered by the inflowing gas and then escaped about the base. The gas thus could be considered as a sample covering an area equal to the bottom of the case, a circle 5 c.m. radius. We have now seen that by the radioactivity of a substance is meant the liberation of positive and negative electrons from the substance; that the amount of such liberation is proportional to the surface exposed and is measured by the rate at which an electroscope loses its charge. This loss of charge will be proportional to the bombardment received by the gold-leaf and this in turn will depend upon the surface exposed normal to the bombardment, *i. e.*, parallel to the bottom of the case.

We now require to know the relation between the loss of charge and the change in the angle of the leaf. This may be had as follows: The surface of one side of the gold-leaf is $b.L$, and the surface exposed parallel to the bottom of the case will be $b.L.sin\theta$. If R_1 be the radioactive constant of the *gas* (or sample), the loss of charge in time dt will be

$$dQ = R_1.b.L.\sin\theta.dt \text{ and}$$

$$dQ/dt = R_1.b.L.\sin\theta \ldots\ldots\ldots\ldots (2)$$

We may now equate equations (1) and (2) from which we get

$$R_1 = \frac{Mg}{F_o b}\cot\theta\left[\frac{d\theta}{dt}\right] \ldots\ldots\ldots\ldots (3)$$

If the standard be now used then we have,

$$R_s = \frac{Mg}{F_o b}\cot\theta\left[\frac{d\theta}{dt}\right] \ldots\ldots\ldots\ldots (4)$$

where p is the mass per sq.c.m. of the gold-leaf.

Lastly if the same value of θ be present in (3) and (4) then we get

$R_1 : R_s : : (d\theta/dt)_1 : (d\theta/dt)_s$ from which we get

$R_1 = R_s(d\theta/dt)_1 \div (d\theta/dt)_s$.

Allowance must now be made for the difference in area exposed in the two cases. Thus if the standard be spread over a circle of radius r_s while the gas (or sample), cover a circle of radius r_1 then

$$R_1 = R_s\left(\frac{r_s}{r_1}\right)^2\left(\frac{d\theta}{dt}\right)_1 \div \left(\frac{d\theta}{dt}\right)_s \ldots\ldots\ldots\ldots (5)$$

Determination of dθ/dt.—It is seen from equation (5) that in the experimental work the objective aimed at is the determination of the time rate of change of the angle which the gold-leaf makes with the vertical. This is done as follows: The electroscope is charged, the flow of gas started through the electroscope case and the angle on the scale read at stated intervals of time. A curve is next platted using time (t) as abcissas (x) and the corresponding angles (θ) as ordinates (y). For any point on this curve we have $dy/dx=d\theta/dt$. In the present work the value of θ was taken at 30° in all cases.

Experimental Work.—The experimental work was divided into two parts: First, that done in the Physical Laboratory of Colorado College, Colorado Springs, and second, that done at the springs in Manitou. The work done in the laboratory was on bottled water and on boiled down residues. It was also interesting to note the difference in the air leakage curves for the laboratory and for the Manitou springs air. During the first part of the Manitou tests the gas was not freed from water vapor. After the work was started apparatus was used to dry the gas and also to measure the rate of flow of the gas. The arrangement of this apparatus is shown in Fig. 3, where *A* is the gas intake, *B* a bubble counting apparatus, *C* a drying tube and *D* the electroscope.

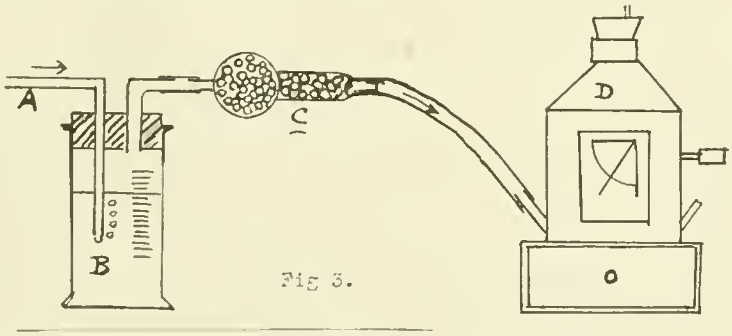


Fig 3.

Data.—The data were arranged under the following heads:

I. Data taken in the Physical Laboratory, Colorado College.
 a. Air leakage curves, to be used in the correction of other curves.
 b. Curves taken with radioactive standard.
 c. Tests on boiled down residues.
II. Data taken in Manitou.
 a. Air curves.
 b. Radioactive standard.

c. Tests on fresh water.

d. Tests on gas.

Representative data are given under each of the foregoing heads.

I. Apparatus set up in southwest basement room of Palmer Hall.

Table 1.—Air curve. Data taken March 29, 1904:

Angle	*Hour*	*Minute*	*Time*
74°	9	0	0
71	10	15	1 hr. 15 min.
68	11	30	2 " 30 "
66	12	0	3 " 0 "
58	1	45	4 " 45 "
46	4	7	7 " 7 "
44	4	30	7 " 30 "
33	6	10	9 " 10 "
22	7	38	10 " 38 "
5	9	45	12 " 45 "
Taken March 30:			
36	9	40	0
19	11	35	1 " 55 "
14	12	15	2 " 25 "

Table 2.—Standard covering circle 2 c.m. radius. Data taken March 31 Time taken with stop-watch.

From	70°	To	50°	40 Sec.
"	40	"	20	25·6 "
"	50	"	30	18·2 "
"	20	"	5	16·2 "
"	45	"	20	26·4 "
"	80	"	70	73·2 "
"	60	"	40	27·8 "
"	30	"	10	23 "
"	60	"	40	27·6 "
"	20	"	10	10 "
"	30	"	10	19 "
"	80	"	70	71·2 "
"	60	"	40	39 "

Table 3.—April 2nd. Two quarts of water from the Ute Chief Spring were boiled to dryness; some of the residue was immediately placed in the slide d covering a circle 2 c.m. radius.

Angle	*Hour*	*Minute*	*Time*
72°	8	42	0
68	9	30	48 min.
63	11	10	2 hr. 38 min.
59	12	23	3 " 41 "
52	1	58	5 " 16 "
33	5	20	8 " 38 "
14	8	0	11 " 42 "

This curve is identical with the air curve.

II. *Data taken in Manitou.*—The Manitou tests were confined to the first group of springs cited above. The apparatus was set up in the spring house of the Navajo spring, a small circular one-roomed structure built over the spring. The spring is capped by a metal bell set in cement. All of the CO_2 gas is caught and piped to the bottling works near at hand. The house is kept closed to the public and was placed at our service through the courtesy of the Manitou Mineral Springs Co. In Fig. 4 is seen the Navajo spring house with the Manitou spring pavilion in the back ground.

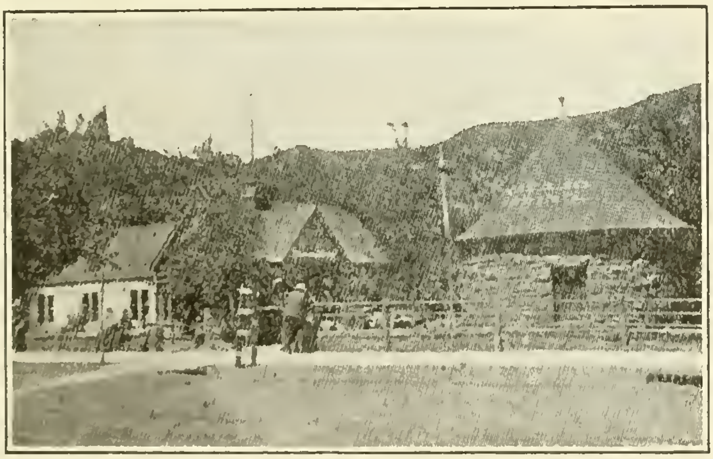


Fig. 4.

Table 4.—Air curve; taken April 5.

Angle	*Hour*	*Minute*	*Time*
40°	1	1	0
30	1	19	18 min.
20	1	37	36 "

Table 5.—Standard covering circle 1.5 c. m. radius.

Angle				*Time (taken with stop-watch)*
From	30°	To	10°	35 Sec.
"	40	"	10	53 "

Table 6.—Fresh water from the Manitou Spring. The water, on a watch glass covered a circle 2.5 c. m. radius.

Angle	*Hour*	*Minute*	*Time*
27°	1	57	0
21	2	11	14 min.
20	2	14	17 "
10	2	46	49 "

From 20° To 10° 32 min. 40 sec. by stop-watch.

Table 7.—Tests on wet gas from the Navajo Spring. The gas was drawn from the bell covering the spring and was passed direct into the electroscope by means of a rubber tube.

Ang'e	*Hour*	*Minute*	*Second*	*Time*
64°	10	54	0	0
56	"	56	0	2 min.
45	"	58	0	4 "
80	11	2	0	0
75	"	6	30	4 " 30 sec.
65	"	10	15	8 " 15 "
60	"	11	30	9 " 30 "
50	"	13	30	11 " 30 "
40	"	15	15	13 " 15 "
30	"	16	45	14 " 45 "
10	"	18	50	16 " 50 "
70	"	23	15	0 "
60	"	26	30	3 " 15 "
40	"	30	15	7 " 0 "
30	"	31	40	8 " 25 "
20	"	32	45	9 " 30 "
10	"	33	55	10 " 40 "

By Stop-watch.

From	80°	To	60°	9 min. 45 sec.
"	50	"	40	2 " 37 "
"	30	"	10	2 " 13 "
"	70	"	60	3 " 2 "
"	40	"	30	1 " 26 "

In the above tests of April 5, tables 4 to 7, the gas was not free from moisture nor was the rate of gas flow known. The apparatus shown in Fig. 3 was now set up.

Table 8.—Air Curve. April 16.

Angle	*Hour*	*Minute*	*Time*
55°	3	54	0
52	4	1	7 min.
49	4	16	16 "
45	4	25	31 "

Table 9.—Standard covering circle 1 c. m. radius.

Angle	*Hour*	*Minute*	*Second*	*Time*
50°	3	10	30	0
45	"	11	10	40 sec.
40	"	11	43	1 min. 30 sec.
35	"	12	16	1 " 46 "
30	"	12	48	2 " 18 "
25	"	13	21	2 " 51 "
20	"	13	45	3 " 15 "

Table 10.—Fresh water from the Navajo Spring, covering circle 3 c. m. radius.

55°	"	23	0
52	"	28	5 min.
50	"	30	7 "
45	"	43	20 "
40	"	53	30 "

Table 11.—Test on dry gas from the Navajo Spring.

	40°	2	40		0
A	23	"	46		6 min.
	15	"	48		8 "
	55	"	49	25	0
	50	"	51	2	1 min. 37 sec.
	45	"	53	0	3 " 35 "
B	40	"	54	25	5 " .. "
	35	"	56	3	6 " 38 "
	30	"	57	31	8 " 6
	25	"	59	2	9 " 37 "
	20	3	0	38	11 " 13 "
C	50°	4	25	3	0
	45	"	27	50	2 min. 47 sec.
	40	"	29	16	4 " 13 "
	35	"	30	52	5 " 49 "

C	30	4	32	22	7 min. 19 sec.
	25	"	33	47	8 " 44 "
	20	"	35	7	10 " 4 "
	15	"	36	40	11 " 37 "

Rate of Gas flow; Head of water in B (Fig. 3), 10 divisions.

Table A......	178	bubbles	in	50	sec.
	108	"	"	30	"
	38	"	"	10	"
	70	"	"	20	"
	104	"	"	30	"
	105	"	"	"	"
	108	"	"	"	"
	104	"	"	"	"
Table B.......	88	"	"	"	"
	94	"	"	"	"
	89	"	"	"	"
Table C......	180	"	"	"	"

Averages—Table A, 217 bubbles per minute.
" B, 181 " " "
" C, 180 " " "

In platting the three part, A, B and C, of table 11, it was found that the three curves were identical, showing that the fall in angle to be independent of the rate of gas flow. It was therefore assumed that in all cases the gas filled the bottom of the case and escaped about the sides. The rate of gas flow is therefore not used in the calculations.

Tests of the Cheyenne Spring.—This spring lies some fifty or more feet to the west of the Navajo spring and is housed in a similar structure. The capping of the spring was, however, not so perfect, and the air was much damper. Tests were made both on wet and dry gas, but the bubble apparatus was not used. The following data were taken on April 30, 1904.

Table 12.—Air Curve, April 30.

Angle	*Hour*	*Minute*	*Second*	*Time*
60°	4	1	42	0
55	"	5	21	3 min. 39 sec.
50	"	9	7	7 " 25 "

Angle	*Hour*	*Minute*	*Second*	*Time*
44	4	13	44	12 min. 2 sec.
40	“	15	33	13 “ 51 “
35	“	21	12	19 “ 30 “
30	“	24	4	22 “ 22 “
25	“	29	10	27 “ 28 “
20	“	32	17	30 “ 35 “

Table 13.—Standard covering circle 1 c. m. radius.

45°	3	56	27	0
35	“	57	16	49 sec.
30	“	57	47	1 min. 20 sec.
25	“	58	16	1 “ 49 “
20	“	58	45	2 “ 18 “
15	“	59	15	2 “ 48 “

Table 14.—Wet gas from Cheyenne Spring.

45	2	51	55	0
40	“	53	37	1 min. 42 sec.
35	“	55	46	3 “ 59 “
30	“	57	12	5 “ 17 “
25	“	58	41	6 “ 46 “
20	3	0	0	8 “ 5 “
15	“	1	27	9 “ 32 “
54	“	4	53	0
50	“	5	30	37 sec.
45	“	6	1	1 min. 8 sec.
40	“	7	2	2 “ 9 “
34	“	8	27	3 “ 34 “
30	“	9	13	4 “ 20 “
25	“	10	17	5 “ 24 “
20	“	11	16	6 “ 23 “

Table 15.—Dry gas from Cheyenne Spring.

55°	“	19	34	0
50	“	20	42	1 min. 8 sec.
45	“	22	19	2 “ 45 “
40	“	23	35	4 “ 1 “
30	“	26	0	6 “ 26 “
25	“	27	40	8 “ 6 “
20	“	28	38	9 “ 4 “
48	“	40	16	0
40	“	42	12	1 “ 56 “
35	“	43	16	3 “ .. “
30	“	44	6	3 “ 50 “
25	“	45	7	4 “ 51 “
20	“	45	57	5 “ 41 “

Discussion of Data.—The data of tables 1 to 3, inclusive, are platted on Curve Sheet I; the data of tables 4 to 7, inclusive, are platted on Curve Sheet II; the data of tables 8 to 11, inclusive, are platted on Curve Sheet III; the data of tables 12 to 15, inclusive are platted on Curve Sheet IV.

In using these curves for determining the value of $d\theta/dt$ it is necessary to use the same angle value in all cases. The value 30° was selected for this purpose. An inspection of the curve sheets shows that the air curves are straight lines and that all of the curves are approximately so for 30° and below.

The following results are derived from the several tables and curves.

Table 1, Air curve; Curve A Sheet I, Value of $d\theta/dt$.... 0·008
Table 2, Standard; Curve B, Sheet I, Value of $d\theta/dt$....12·
Table 3, Residue; Curve A, Sheet I, Value of $d\theta/dt$..... 0·008

thus showing that this residue from boiled down water is not radioactive, since the value of $d\theta/dt$ is the same as that for air.

Table 4.—Air curve for the Navajo spring house, Manitou. The value of $d\theta/dt$ is 0·11 showing an apparent high leakage as compared with the air of the laboratory at Colorado College. This is due to the greater humidity and the presence of escaping gas.

Table 5.—Standard covering a circle 1·5 c.m. radius. The value of $d\theta/dt$ is 6·9. The standard use was a sample of pitchblende which Professor Wolcott had compared with metallic Uranium finding it to be 3·5 times as radioactive as is Uranium. This value, 3·5, is therefore used as the radioactive constant of the standard in the present investigation.

Table 6.—Fresh water from the Manitou spring. As examined no radioactivity is shown, the value of $d\theta/dt$ not being greater than that for air. In fact this method of water examination is not suitable, and the better method of passing air through the water and of then examining the air, was not attempted.

Table 7.—Wet gas from the Navajo spring. Curve E, Sheet II, gives the curve corrected for air leakage. The value of $d\theta/dt$ is 1·59 and the value of the radioactive constant of the gas as determined by equation (5) is,

$$R=\frac{3{\cdot}5\times1{\cdot}59\,(1{\cdot}5)^2}{6{\cdot}9\times(5)^2}=0{\cdot}0726 \text{ Uranium.} =49{\cdot}9 \text{ I}\times10^3\text{E.S.}$$

Table 8.—Air leakage curve; same as table 4, but for new gold-leaf and changed date. The value of $d\theta/dt$ is 0·075.

Table 9.—Standard covering circle 1 c.m. radius. The value of $d\theta/dt$ is 2·21.

Table 10.—Fresh water from the Navajo spring; see discussion under table 6.

Table 11.—Dry gas from Navajo spring.. Curve E, Sheet III, shows this table corrected for air leakage. The value of $d\theta/dt$ is 0·645 and the value of the radioactive constant is,

$$R=\frac{3{\cdot}5\times0{\cdot}645\times(1)^2}{6{\cdot}9\times(5)^2}=0{\cdot}041 \text{ U.} =28{\cdot}4 \text{ I}\times10^3\text{E.S.}$$

Table 12.—Air curve for the Cheyenne spring, shown in Curve A, Sheet IV. The value of $d\theta/dt$ is 0·26 showing a humid atmosphere or one into which a good deal of gas had escaped. The conditions present indicated that the bell over the spring allowed the escape of gas.

Table 13.—Standard covering circle 1 c.m. radius. Curve B′, Sheet IV, gives this table corrected for air leakage. The value of $d\theta/dt$ is 1·88.

Table 14.—Wet gas from the Cheyenne spring. Curve C′ sheet IV gives this table corrected for air leakage. The value of $d\theta/dt$ is 1·08 and the value of the radioactive constant is,

$$R=\frac{3{\cdot}5{\cdot}1{\cdot}08{\cdot}(1)^2}{1{\cdot}9{\cdot}(5)^2}=0{\cdot}735 \text{ U.} =50{\cdot}6 \text{ I}\times10^3\text{E.S.}$$

Table 15.—Dry gas from Cheyenne spring. Curve D′, Sheet IV. The value of $d\theta/dt$ is 0·555 and the value of the radioactive constant is,

$$R=\frac{3{\cdot}5\;0{\cdot}56\;(1)^2}{1{\cdot}9\;(5)^2}=0{\cdot}0412 \text{ U.} =28{\cdot}4 \text{ I}{\cdot}10^3\text{E.S.}$$

In the foregoing discussion it will be noticed that the radioactive constant is given in terms of the uranium standard and also in electro-static units. The derivation of the constant in terms of the uranium standard has already been explained. In Bulletin 395 of the U. S. Geol. Survey, Schlundt and Moore give tests of the springs of Yellowstone Park. Their results are expressed in terms of the uranium standard and also in electro-static units. Using these results and having determined the constants for the Manitou springs in terms of the uranium standard it is possible, by simple proportion to derive the corresponding values in electro-static units. The above values were had in this way.

Messrs. Schlundt and Moore give an interesting table (table 8, p. 29), showing the radioactivity of gases from springs in Europe and America. This table is here reproduced, arranged, however, in the order of radioactive values; the European country is also added. All of the tests under the name of Schlundt and Moore are of Yellowstone Park springs. I have also added to this table the two Manitou springs whose tests are given in this paper. It will be seen that the Manitou springs compare very favorably with the famous springs of Europe.

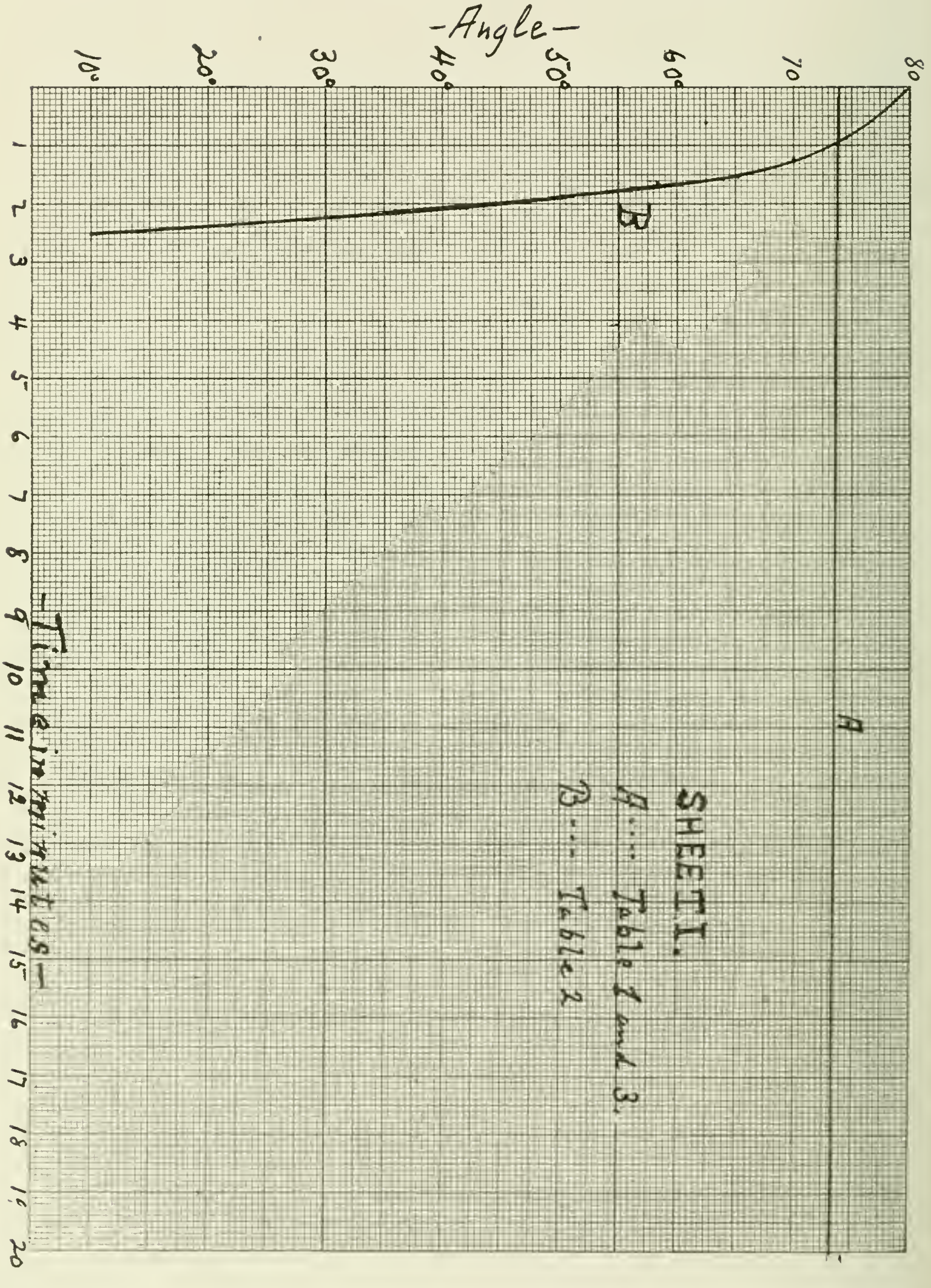
In closing allow me to express a hope that ere long a comprehensive test may be made of the springs of Manitou, using the best of modern apparatus. Such a test would naturally follow the lines persued by Schlundt and Moore in their work on the Yellowstone National Park.

Dept. Physics, Olivet College, Olivet, Michigan, September 12, 1912.

RADIOACTIVITY OF GASES FROM SPRINGS IN EUROPE AND AMERICA.*

Name of Source	*Location*	*Radio-activity E. S. Units $1 \cdot 10^{3}$*	*Observer*
Spring and Pool near Clepsytra Geyser.	Lower Geyser basin.	834	Schlundt & Moore.
Firehole.	Lower Geyser basin.	600	Schlundt & Moore.
Three crater Spring.	Shoshone Geyser basin.	598	Schlundt & Moore.
Grabenbäcken Quelle.	Gastein, Bohemia.	564	Mache.
Elizabeth Stollen.	Gastein, Bohemia.	412	Mache.
Pool near Economic Geyser.	Upper Geyser basin.	353	Schlundt & Moore.
Bench Spring.	Upper Geyser basin.	254	Schlundt & Moore.
Vauquelin.	Plombieres, France.	184	Curie & Laborde.
Mühl-Brunnen.	Karlsbad, Bohemia.	94·2	Mache & Meyer.
Fish Cone.	West Thumb, Yellowstone Lake.	85	Schlundt & Moore.
Schloss-Brunnen.	Karlsbad, Bohemia.	50·2	Mache & Meyer.
Schützenhof Quelle.	Wiesbaden, Germany.	50	Henrich.
Orpiment Pool.	Norris Basin.	47	Schlundt & Moore.
Cheyenne Spring.	Manitou, Colorado.	28·4	Shedd.
Navajo Spring.	Manitou, Colorado.	28·4	Shedd.
Bains des Dames.	Luxeuil, France.	23	Curie & Laborde.
Urquelle.	Teplits-Schönau, Bohemia.	21·9	Mache & Meyer.
Chomel.	Vichy, France.	18	Curie & Laborde.
Johannabad.	Baden, Baden.	16·6	Mache & Meyer.
Nymph Spring.	Tower Falls.	13·3	Schlundt & Moore.
Wald-Quelle.	Marienbad, Bohemia.	10·9	Mache & Meyer.
Haupt-Quelle.	Fischau, Austria.	2·60	Mache & Meyer.
Herrenbad-Quelle.	Fischau, Austria.	2·18	Mache & Meyer.
Markt-Brunnen.	Karlsbad, Bohemia.	1·51	Mache & Meyer.
Ambrosius-Brunnen.	Marienbad, Bohemia.	1·48	
Viktoria-Brunnen.	Oberlahnstein, Germany.	1·25	Borne.

*U. S. Geol. Sur. Bulletin 395, page 29.


-Angle-
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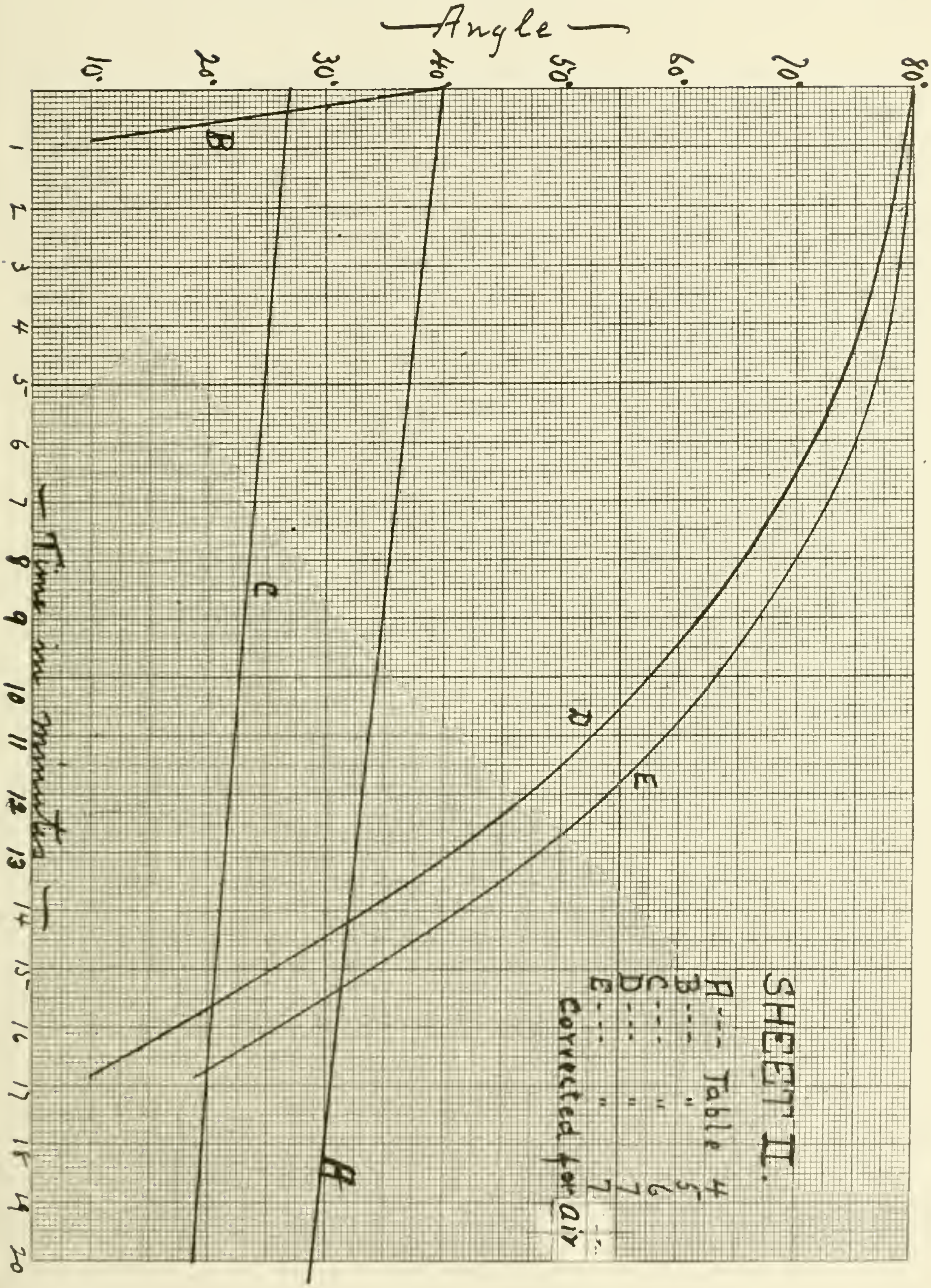
B
A
SHEET I.
A... Table 1 and 3.
B... Table 2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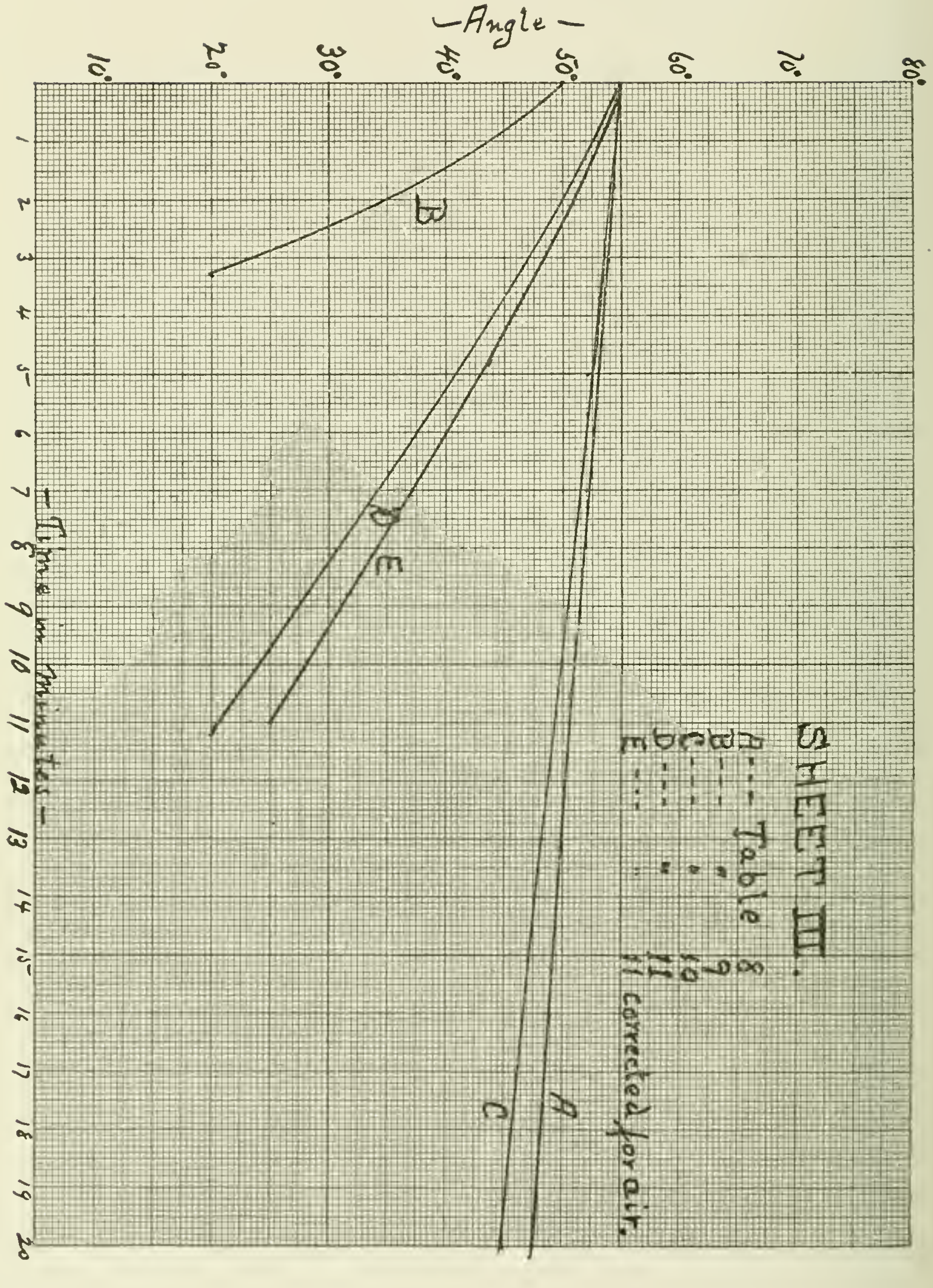
A
B
C
D
E
SHEET II.
A -- Table 4
B -- " 5
C -- " 6
D -- " 7
E -- " 7
Corrected for air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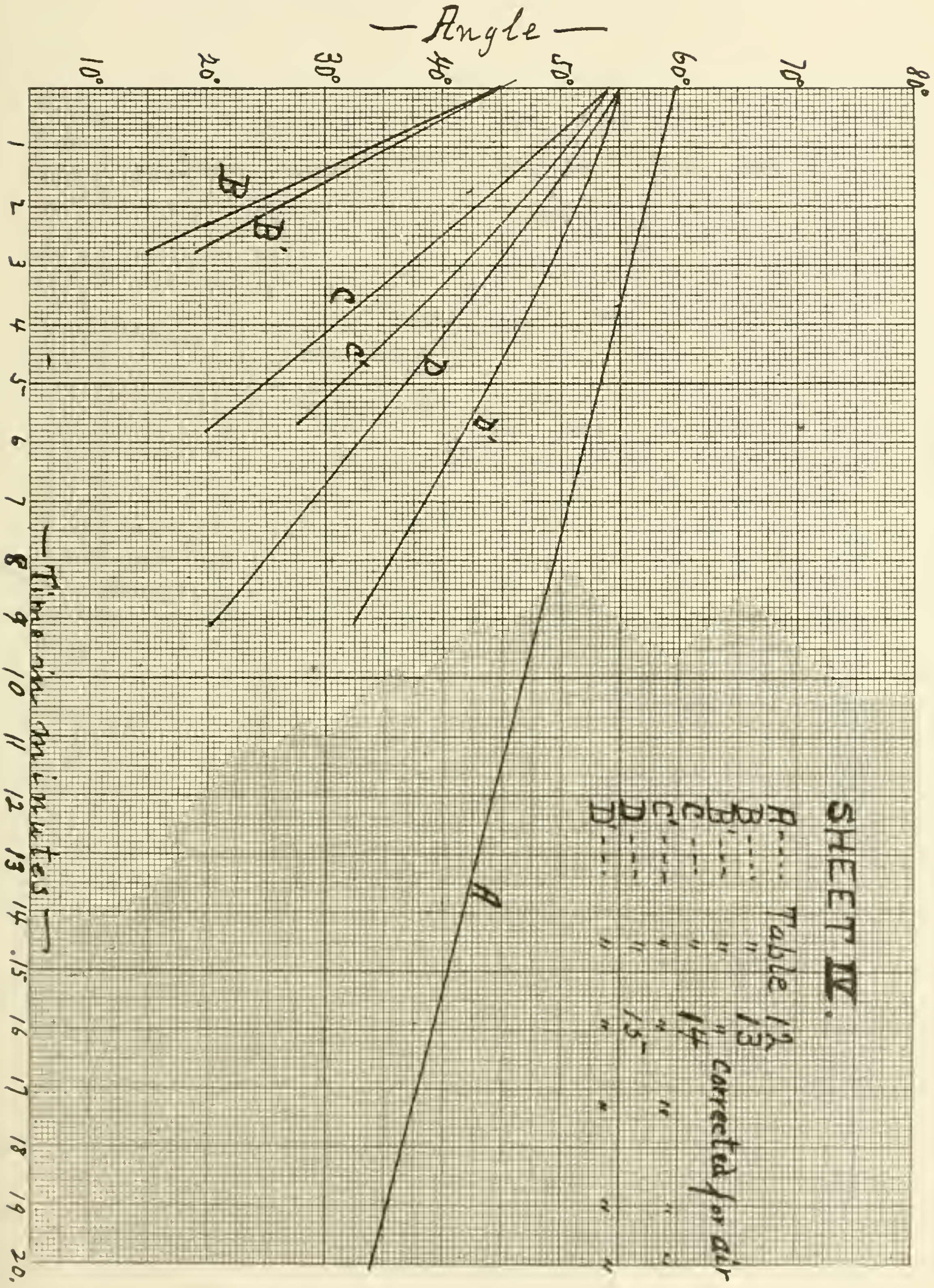
D
E
SHEET III.
A--- Table 8
B--- " 9
C--- " 10
D--- " 11
E--- " 11 corrected for air.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B
B'
C
C'
D
D'
A
SHEET IV.
A---- Table 12
B---- " 13
B'---- " " corrected for air
C---- " 14
C'---- " " " "
D---- " 15
D'---- " " " "

PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY.
VOL. X, pp: 265-278.

INVESTIGATION OF ROOF-SHALE DUST WITH REFERENCE TO ITS ADAPTABILITY AS A DETERRENT IN COAL-DUST EXPLOSIONS.

(Read at the Meeting of the Society, June 7, 1913.)

By Richard C. Hills.

The present paper is the result of an investigation into the adaptability of the roof shales of the Delagua mine, Las Animas county, Colorado, for use as stone-dust in the prevention or mitigation of coal-dust explosions. The work was undertaken at the instance of Mr. W. J. Murray, general manager of the coal mines of The Victor-American Fuel Company, the owners of the Delagua mine.

In the present paper no attempt has been made to treat the subject of mine explosions in detail, but merely to offer a few introductory remarks that will serve to explain the object of the investigation.

Until the latter part of the last century it was the accepted belief that explosions in coal mines were due solely to the ignition of inflammable gases, chiefly marsh gas, which is the principal constituent of the much dreaded "fire damp." It is now well known that, while "fire damp" in sufficient quantity will produce a disastrous explosion, and when present in small quantity may initiate one, the chief cause of the tremendous force developed by a coal mine explosion is the coal dust in the mine workings.

It is not necessary that the amount of coal dust in the mine atmosphere should be sufficient to render it explosive under ordinary conditions. The presence of a comparatively small amount may suffice to propagate an explosion initiated at a remote point: for example, were the coal is being broken down and loaded into the pit-cars; or where, from any cause, the formation of dust renders the atmosphere locally explosive.

As soon as the inflammable nature of coal dust became generally recognized, several methods were suggested whereby explosions might be prevented or the effects minimized.

Sprinkling the mine frequently with water has been resorted to in the majority of cases and the use of hygroscopic compounds, such as calcium chloride which, when mixed with the dust, would cause the surface to be always moist, has been strongly advocated.

It is doubtful if sprinkling with water serves any useful purpose, other than to "lay" the dust. Indeed, it is certain that a large part of the impalpable powder that otherwise would pass out through the "return" is by such means accumulated in the mine in a wet, often muddy, condition, which when an explosion occurs is caught up and completely atomized by the terrific force of the blast. There is thus formed, in the front of the advancing flame, a dense cloud of highly inflammable material, through which the explosion is propagated with increased acceleration of power and velocity. Hence, "sprinkling" is, in effect, one way of augmenting the amount of potentially explosive material accumulating in a mine, while from a hygienic standpoint the maintenance of an ultra-humid atmosphere, where men are constantly and strenuously working, is open to serious objection.

The use of dustless zones was also resorted to, but was found to be of small value in preventing the extension of an explosion.

Another method, and one that deserves more consideration than it has hitherto received in this country, is the application of stone-dust, as developed during the last four years at Altofts colliery in England. This method has been well described by Mr. William Edward Garforth in his presidential address delivered before The Institution of Mining Engineers of Great Britain.*

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*General Meeting at London, June 6, 1912.

This method consists in the distribution of finely crushed shale dust along the roadways, on the rough surfaces and ledges along the walls and on board shelves arranged to the right or left near the roof, according to circumstances. The shale dust is distributed either by hand or by machine—we would prefer the latter in this country, owing to the high price of labor.

The proportion of shale dust used is from ten to twelve times the quantity of coal dust present; an amount that should be amply sufficient, since the Altofts gallery experiments demonstrated that a mixture of equal weights of coal dust and shale dust was not explosive, even when the amount of coal dust present was five times as much as caused explosion when pure coal dust was used.*

A study of the conditions in the Silkstone pit following the explosion of 1886 seems to have first suggested the use of shale dust as a deterrent. It was there observed that the return airways contained a large quantity of shale dust formed by the wearing away of the floor by the feet of men and horses, these airways being used as traveling roads. The intake roads contained coal dust only and the explosion was found to be confined to these roads notwithstanding that the stoppings were blown out and the blast penetrated into the return airways, yet in no instance was the explosion propagated along these airways. Subsequent experiments in the Altofts gallery fully confirmed the observations in the Silkstone pit.

The stone dust used at Altofts is obtained by finely pulverizing the argillaceous shale "ripped" or "brushed" from the roof to increase the height in the roadways. Roof shale is preferred to any other rock for this purpose, since in addition to its being a waste product it best meets the following requirements:

(1) The crushed dust should have a low specific gravity to insure the maximum amount of flotation when thrown into the mine atmosphere.

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*William Edward Garforth, loc. cit.

(2) It should not contain hard, splintery, insoluble grains of such substances as quartz, which when brought in contact with animal tissues produce irritation.

(3) The rock should be soft, that it may pulverize readily into rounded particles.

(4) The degree of solubility in weak solvents should be high, that the irritating asperities of inhaled particles may be dissolved by the fluids of the body.

(5) The percentage of carbonaceous matter should be low.

Mr. Garforth recommends that distilled water, dilute hydrochloric acid and digestive fluid be employed in solubility determinations. Likewise the estimation of the percentage of magnetic particles which may be produced by the use of iron in pulverizing, especially if the rock is hard or contains sharp, cutting grains.

He gives the following determinations on the Altofts shale dust, which may be taken as a guide in estimating the adaptability of other shales, as follows:

Specific Gravity	*Magnetic Particles*	*Soluble in Distilled Water*	*Soluble in Dilute Hydrochloric Acid*	*Soluble in Digestive Fluid*
2·65	2·70	2·186	6·886	2·557

The success attending the use of shale dust in the Altofts colliery led Mr. W. J. Murray to adopt this method, tentatively, in several of the mines of The Victor-American Fuel Company.

Pending a thorough examination into the merits and adaptability of the different shales available, dust gathered off the roads has been used for the time being to mitigate the effects of an explosion should one occur.

The samples examined include six of roof shales, one of road dust and one of the ordinary loam of the country. The shale samples were from different parts of the Delagua mine and were all carefully selected by Mr. Samuel Dean, inspector of the mine, an educated engineer and a man deeply interested in the use of shale dust in coal mines.

GEOLOGICAL AGE OF THE SHALES.

The workings of the Delagua mine are on the upper workable seam of the upper coal group of the Raton coal field. In mapping the geology of the Spanish Peaks quadrangle, in which the mine is located, the writer placed the base of the Lower Eocene above the horizon of the upper coal group and the entire series of coal-bearing beds down to the Trinidad sandstone (Fox Hills) was referred to the Laramie in accordance with the identification of the fossil flora by Dr. Newberry.*

Recently, however, W. T. Lee, in his studies of the same measures in the adjoining quadrangle to the south, discovered the existence of a well marked unconformity about 300 feet above the base of the coal series.†

A critical study of the rich fossil flora by Dr. Knowleton has developed the fact that the measures below the unconformity are of Montana age, or nearly equivalent to the Mesa Verde coal group west of the main range, while the measures above the unconformity are of the same age as the Denver formation, which he regards as lowest Eocene.¶ Thus confirming the views advanced by Dr. Cross § as to the Eocene age of the Denver beds.

The lower of the two formations has been named the Vermejo and the upper one the Raton. The unconformity between them can be traced northward into southern Colorado, though structurally it would not appear in that part of the measures. Its position is about 500 feet below the plane of the Delagua seam. Hence, assuming the correctness of Dr. Knowleton's correlation, the measures at the Delagua horizon are of Lower Eocene age.

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*Geologic Atlas of the United States, No. 71, Spanish Peaks Folio, Geology by R. C. Hills.

†Bull. Geol. Soc. Am. Vol. 23, pp. 571-686, 1912.

¶Am. Jour Sci. Vol. 35, pp. 526-530, May, 1913.

§Am. Jour. Sci. (3) Vol. 37, pp. 261-282, 1889. Proc. Wash. Acad Sci. Vol 11, p. 42, 1909.

This statement might lead to the inference that shales of that age would be less firmly consolidated than the Altofts shale, which is of Carboniferous age. It is a question, however, if in this respect there is very much difference. The alteration of the original lignite to coking coal, that has resulted from the injection of a large quantity of igneous material into and below the measures, likewise promoted the consolidation of the associated shales and sandstones.

The material of which these rocks is composed was derived from the denudation of the Archæan areas of the Sawatch range to the westward, which furnished chiefly granitic debris.

MICROSCOPIC EXAMINATION OF THE SAMPLES.

It was not practicable in all cases to prepare good thin sections owing to the soft, fragile nature of the material and its tendency to disintegrate in grinding, or upon the application of water, and only after repeated trials could sections be made sufficiently thin for work with the microscope.

Sample No. 1.—From Twenty-seven East, Second North—Taken Four Inches Above the Roof Coal.

The rock is dark shale of medium texture containing thin, paper-like lamellæ of coal arranged in parallel layers. A satisfactory thin section could not be made. The 60-mesh powder, when viewed under a power of 23 diameters in transmitted light shows numerous grains of coal mingled with those of shale, the latter heavily stained with iron oxide, with more or less finely disseminated carbonaceous matter. Some of the larger grains are thin and flaky and many show sharp or splintery asperities. An illustration of the magnified powder is given in the left-hand figure, Plate IV.

It is evident at a glance that shale of this character is not suitable for continued use as stone dust. Outside of the tendency to flake and splinter, the amount of coal present is prohibitive. The examination, however, illustrates very strongly one kind of sale that *cannot* be utilized for this purpose.

Sample No. 2.—From Twenty-seven East, Second North.—Taken Ten Inches Above the Roof Coal.

Dark shale, rather soft and unctuous to the feel. Shows a little pyrite and contains thin, parallel lamellæ of coal and more or less disseminated carbonaceous matter. With considerable difficulty a thin section was prepared for study under the microscope. In parallel light there are small areas that are transparent and colorless, with larger translucent areas stained with iron oxide, and other areas and grains that are sub-translucent and heavily impregnated with the same substance. The grains are probably siderite. Between crossed Nicols the transparent areas exhibit aggregate polarization in pale-gray tints, common to a rock resulting from the consolidation of fine arkose sediments.

The presence of so much iron, mostly in the ferrous state, as shown in the course of the solubility determinations, accounts for its rather high specific gravity. A section of this rock is illustrated on Plate II.

Sample No. 3.—From Twenty-six East Parting, Second North.—Taken Three Feet Above the Roof Coal.

Light-gray shale of medium texture and conchoidal fracture, showing but little coal, though there is some carbonaceous matter visible in the filamentary form of leaf imprints. This rock afforded an excellent thin section, which in parallel light exhibits transparent, crystalline areas, with grains of chlorite, branching bodies of iron ore and dark-brown grains which, from the analysis, are thought to be siderite. Between crossed Nicols the transparent portion consists of irregular-shaped grains of orthoclase polarizing in pale, gray and yellowish tones, with a few grains of quartz and muscovite in a groundmass that affords the same polarization as a fine-textured orthoclase aggregate. That all the feldspar present is orthoclase is further indicated by the large predominance of potash over soda in the analysis and by the absence of polysynthetic twinning in any of the grains. A section of this rock multiplied 54 diameters is illustrated on Plate II.

Sample No. 4.—From the Fifth North District.—Taken Nine Inches Above the Roof Coal.

Black, carbonaceous shale, thinly laminated, containing some coal lamellæ, and soft and unctuous to the feel. It was impossible to prepare a thin section of this rock. An examination of the powder shows that it very much resembles No. 1 and that it *cannot* be used as stone dust.

Sample No. 5.—From the Fifth North District.—Taken Six Feet Above the Roof Coal.

Gray shale of conchoidal fracture and fine texture; slightly unctuous to the feel; shows some filamentary carbonaceous matter, but no coal. This rock afforded an excellent thin section, which in parallel light presents a field that is transparent to translucent, according to the amount of iron-mist present. Numerous small grains of iron ore, siderite, also appear. Between crossed Nicols a few orthoclase grains, with shreds of partly altered biotite, are readily discernible in a groundmass that gives aggregate polarization. Quartz is absent. A section of this rock multiplied 87 diameters is shown in the left-hand diagram, Plate III. On the whole, this shale is the best one of the lot, as will appear more fully in connection with the solubility determinations, and the roundness of the grains as illustrated in Plate IV.

Sample No. 6.—From the Fourth North Entry.—Taken Two Feet Above the Coal.

Light-gray shale of medium texture and conchoidal fracture. Rather hard and tough. Shows carbonaceous matter and a few grains of filamentary coal. The rock yielded a very fair thin section, which in parallel light showed transparent and translucent areas nearly equally divided, the latter being stained with iron-mist. Between crossed Nicols a few orthoclase grains appear with a little quartz, some biotite and a few grains of iron ore, probably siderite. This section is illustrated in Plate III.

Sample No. 7.—Sandy Loam From the Soil Near the Mine.

For microscopical work a mount was prepared by mixing a small quantity of the sample with hot Canada balsam on a glass slide, grinding the mixture down to nearly the thickness of a rock section and adding a cover glass. Under the microscope the material is then seen to consist of a predominance of shale grains with more or less quartz, mica, iron ore and vegetable fibre. It contains too much quartz and splintery material to be utilized in place of regular stone dust.

Sample No. 8.—Road Dust Now in Use.

A mount from this dust was prepared in the same way as No. 7. It is illustrated in conjunction with No. 7 in Plate I. The grains are quite coarse and consist largely of crystalline quartz, many of the grains affording a positive interference figure in convergent light. It is not at all adapted for use as stone dust except as a temporary expedient.

CHEMICAL INVESTIGATION.

In conducting the solubility tests in accordance with the recommendation of Mr. Garforth, the air-dried sample was crushed in a porcelain mortar, to avoid the formation of abraded particles of metallic iron, and the crushed material passed through a 60-mesh screen (60 meshes to the linear inch), the size that would probably be employed in the large way.

The solvents used were, distilled water, a 20 per cent. solution of hydrochloric acid of 1·20 specific gravity, and a solution of Elixir lactopeptine, stated by the manufacturers* to contain 38 per cent lactopeptine and 19 per cent alcohol, together with pepsin, pancreatin, diastase and lactic and hydrochloric acids.

The quantity of solution used in each case was 25 cc., which was poured into a small (75 cc.) glass flask containing one gram of the powdered sample. The mixture was frequently agitated during a period of about three hours by imparting to the flask a brisk circular motion. It was then allowed to stand over night at a temperature approximating 98 degrees Fahr. (36·6 degrees C.), the solvent being allowed to act for a total period of 20 hours. In the case of the distilled water and dilute hydrochloric acid tests the contents of each flask was transferred to a beaker, diluted with water, thrown onto a weighed filter and the residual powder washed, dried and weighed.

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*New York Pharmacal Company, Yonkers, N. Y.

In the case of the digestive solution test the procedure is varied, thus: The fluid, which is carmine-colored, is washed into a beaker and diluted to 400 cc., with a 50 per cent. solution of alcohol, allowed to subside and the clear liquor decanted onto a weighed filter. The residue is then repeatedly treated with strong alcohol and ammonia until the organic precipitates, formed by the action of the fluid on the rock, are completely dissolved and there is no longer the faintest lilac tint to the solution. The residual powder is then thrown onto the filter, washed with about 100 cc. of water, finally, once with alcohol, then dried and weighed.

The results obtained are set forth in the annexed table, which includes also the necessary total water determination made in order to estimate the percentage of combustible carbonaceous matter.

Mine Number of Sample	1	2	3	4	5	6	7	8
Specific Gravity - - -	2·273	2·722	2·550	2·585	2·532	2·558	2·430	2·380
Water below 110 degrees C -	·55	1·75	1·20	1·65	1·25	1·30	0·50	0·45
Water above 110 degrees C -	3·50	0·85	3·70	1·85	2·85	0·95	1·05	1·10
Loss on Ignition - - - -	17·40*	11·50†	3·55	17·10*	5·40°	6·75°		
Soluble in distilled water -	1·74	1·67	2·08	2·30§	1·45	1·18	1·63	1·42¶
Soluble in dilute hydrochloric acid	6·70	7·75	8·37	5·78	11·62	7·15	9·28	8·42
Soluble in digestive solution -	1·55	3·37	3·15	3·10	5·15	2·82	4·17	2·63
Percentage of magnetic particles	None	None	None	None	None	None	·47	·32

* Much smoke and tarry vapors.

† Little smoke and tarry vapors.

° No smoke or tarry vapors.

¶ Distinctly pale straw-yellow solution.

§ Solution slightly alkaline.

To render the investigation as thorough as time would permit, complete analyses were made of samples No. 3 and No. 5, the results of which are given in the subjoined table.

ANALYSES OF SAMPLES		*III*	*V*
Silica	(SiO_2)	57·05	57·50
Alumina	(Al_2O_3)	21·95	22·10
Ferric oxide	(Fe_2O_3)	1·49	1·42
Ferrous oxide	(FeO)	4·47	4·25
Manganese oxide	(MnO)	0·97	0·85
Calcium oxide	(CaO)	0·56	0·24
Magnesium oxide	(MgO)	0·26	Trace
Potassium oxide	(K_2O)	3·18	3·12
Sodium oxide	(Na_2O)	0·96	0·84
Water below 110° C	(H_2O)	1·20	1·25
Water above 110° C	(H_2O)	3·70	2·85
Phosphoric acid	(P_2O_5)	0·06	Trace
Carbon dioxide	(CO_2)	0·59	0·46
Sulphuric acid	(SO_3)	0·31	0·34
Titanic acid	(TiO_2)	Trace	Trace
Chlorine	(Cl)	Trace	Trace
Ignition (carbonaceous matter)		3·55	5·40
		100·30	100·62

The methods employed in the analytical determinations are essentially those suggested by Clark and Hillebrand.*

CONCLUSIONS.

Viewed in the light of microscopical and chemical investigation here recorded, it appears that the shale samples that are much less than two feet above the roof coal, contain too much carbonaceous matter to be applicable for use as shale dust in the prevention, or mitigation of coal-dust explosions. This practically excludes samples 1, 2 and 4 from further consideration.

The most satisfactory results are afforded by sample No. 5. The dust is well rounded, the specific gravity is low, the solubilities high and there is a total absence of the objectionable quartz grains. In most respects it is superior to the Altofts shale for the object intended.

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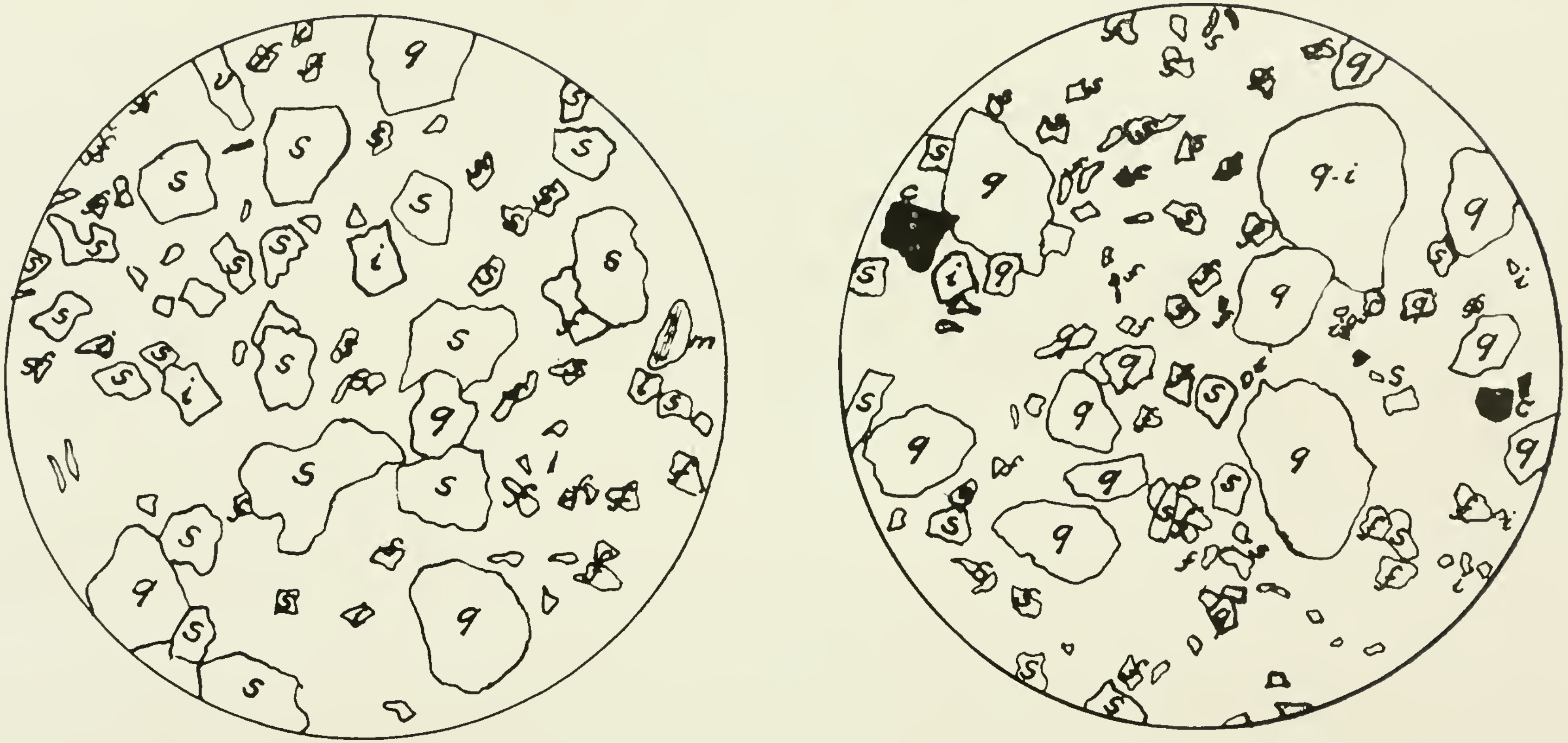
*Analysis of Rocks and Analytical Methods, U. S. Geological Survey, 1880-1896. Bulletin No. 148, 1897.

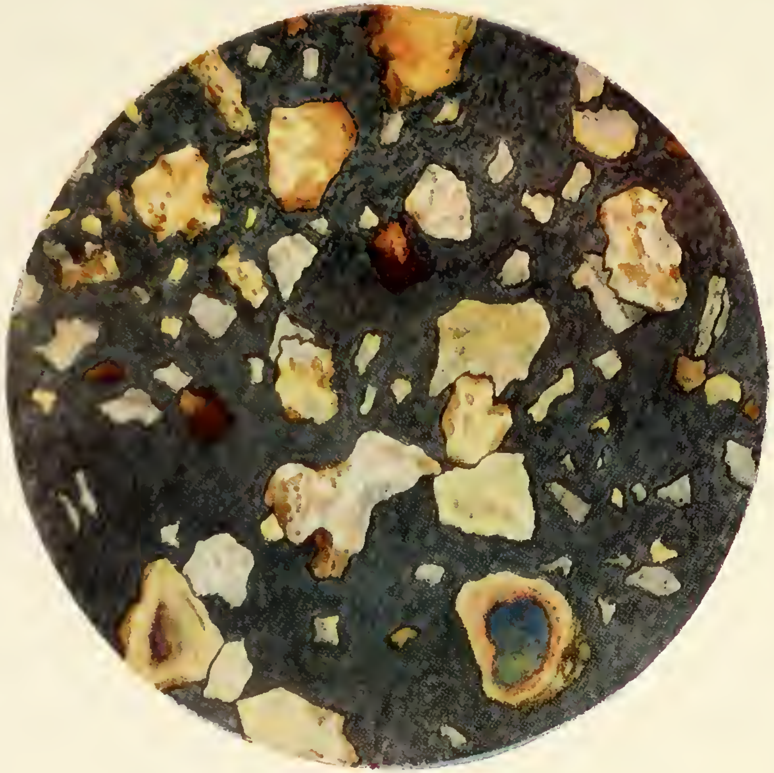
Samples No. 3 and 4, while not equal to No. 5 are, nevertheless, up to the requirements of good shale dust and both can be used without detriment to the health of the coal miners.

In conclusion it should be stated that the investigation here set forth will be followed later on by practical tests on a sufficiently large scale to furnish reliable results. For this purpose, under the supervision of Mr. W. J. Murray, an experimental gallery is now being fitted up at Gray Creek. The results of the experiments will probably be communicated to the Rocky Mountain Coal Mining Association at the next Denver meeting.

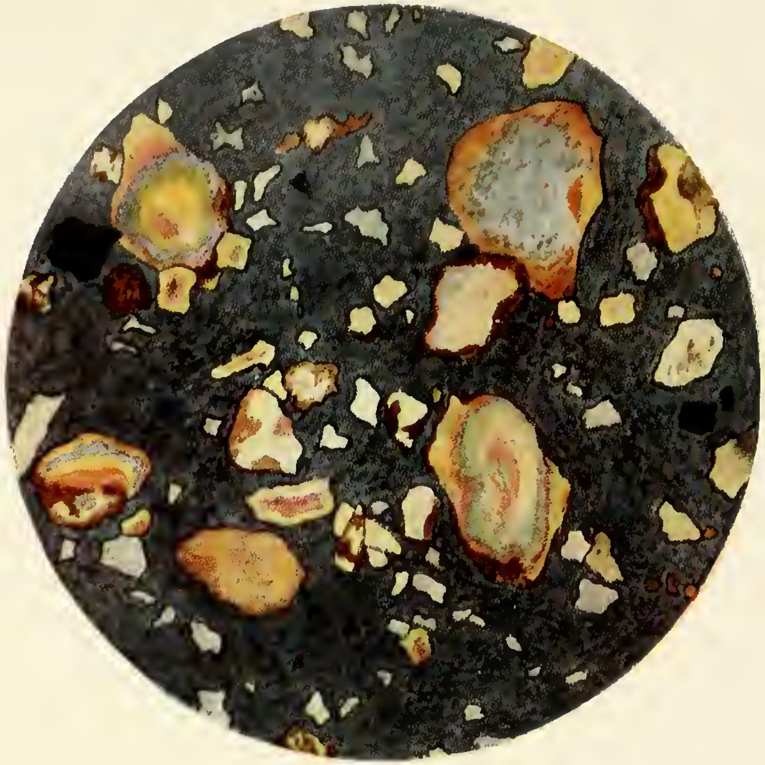
KEY TO SECTIONS 7 AND 8



c. Grains of coal.
f. Grains of feldspar.
i. Grains of iron ore, siderite?
m. Shred of mica, muscovite.
q. Grains of crystalline quartz.
q-i. Grain of quartz showing interference figure.
s. Flakes of shale
v. Vegetable fiber.



Sandy loam, No. 7, X 54 diam.

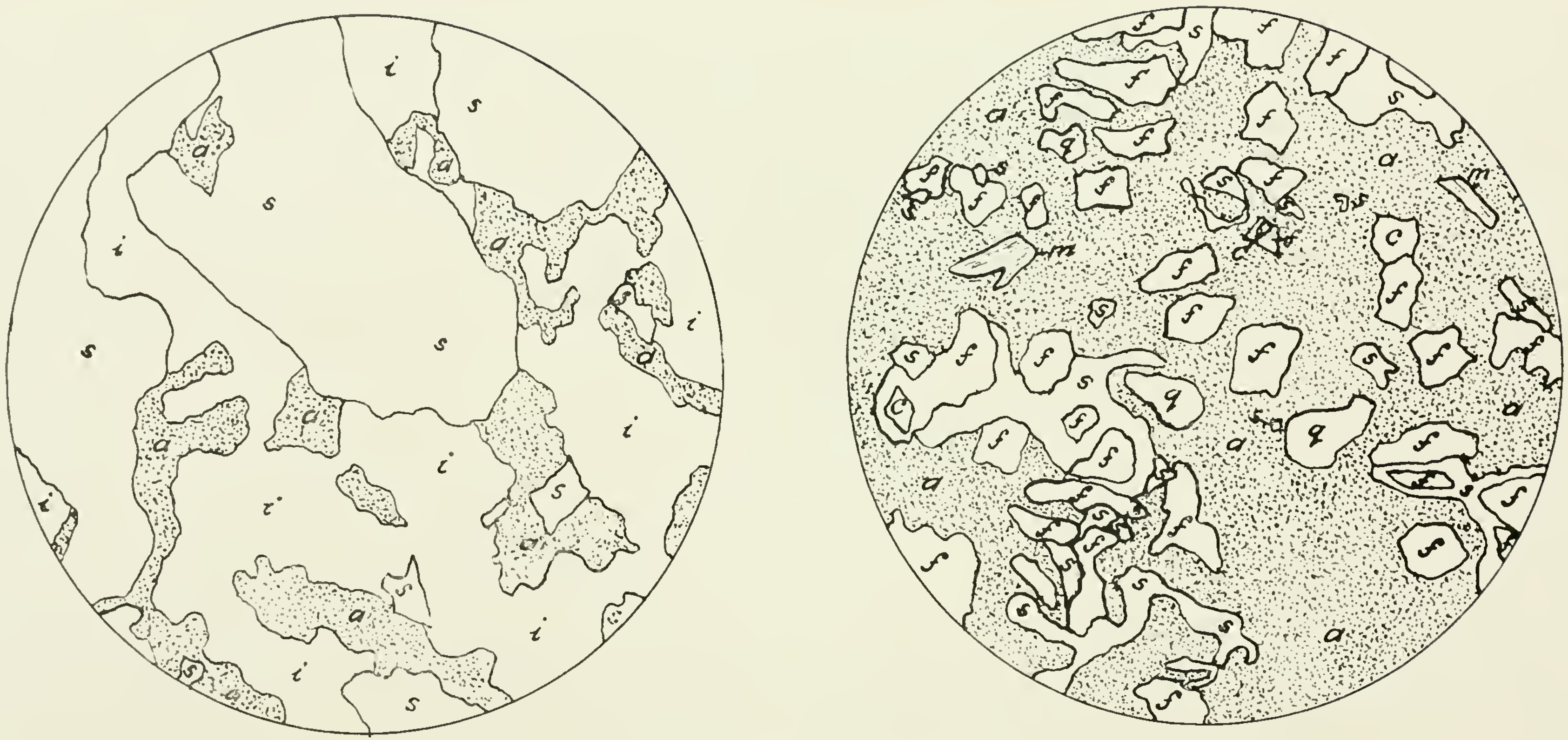


Road dust, No. 8, X 23 diam.

Nicols crossed

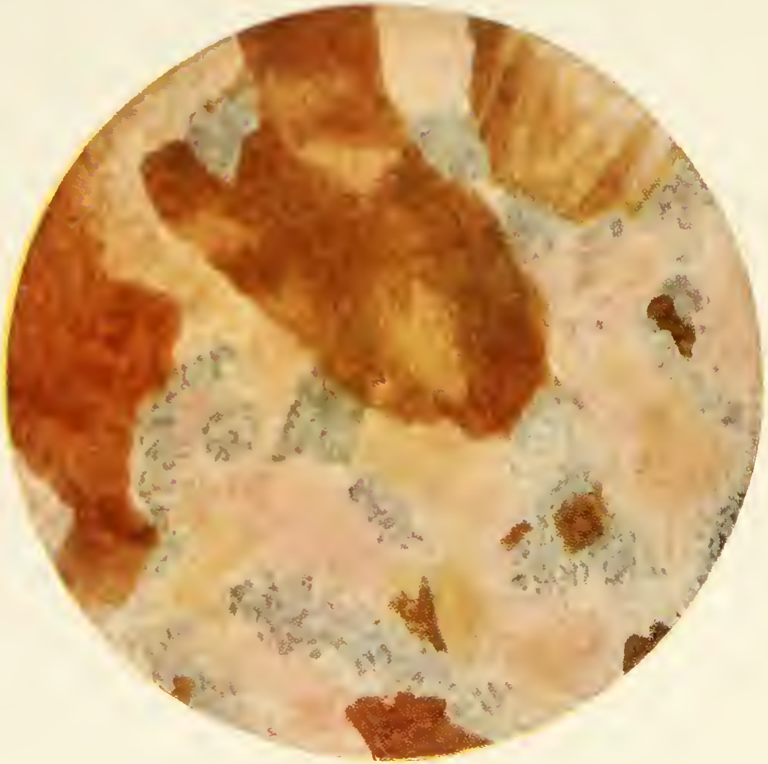
Micrometer scale

KEY TO SECTIONS 2 AND 3

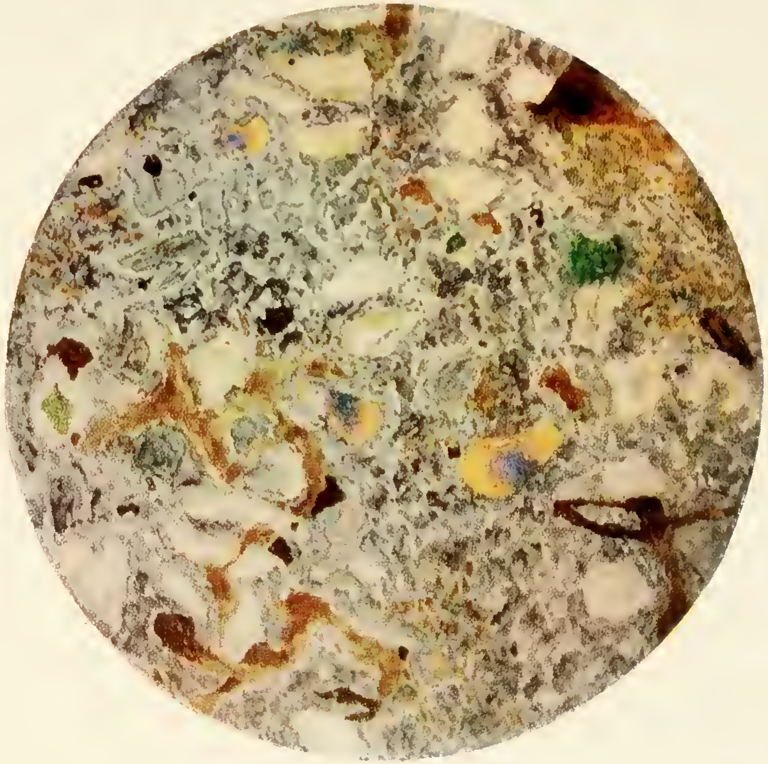


a. Areas of aggregate polarization, mostly orthoclase.
c. Grains of chlorite.
f. Grains of orthoclase feldspar.
i. Areas clouded by iron mist.
q. Grains of crystalline quartz.
m. Shreds of mica, muscovite.
s. Areas and grains of iron ore, grains probably siderite.

PLATE II.



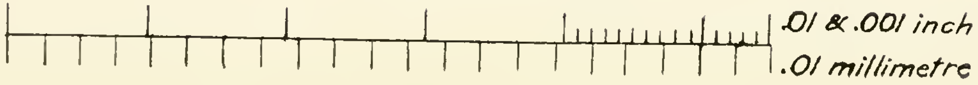
Thin section of No.2, X 54 diameters



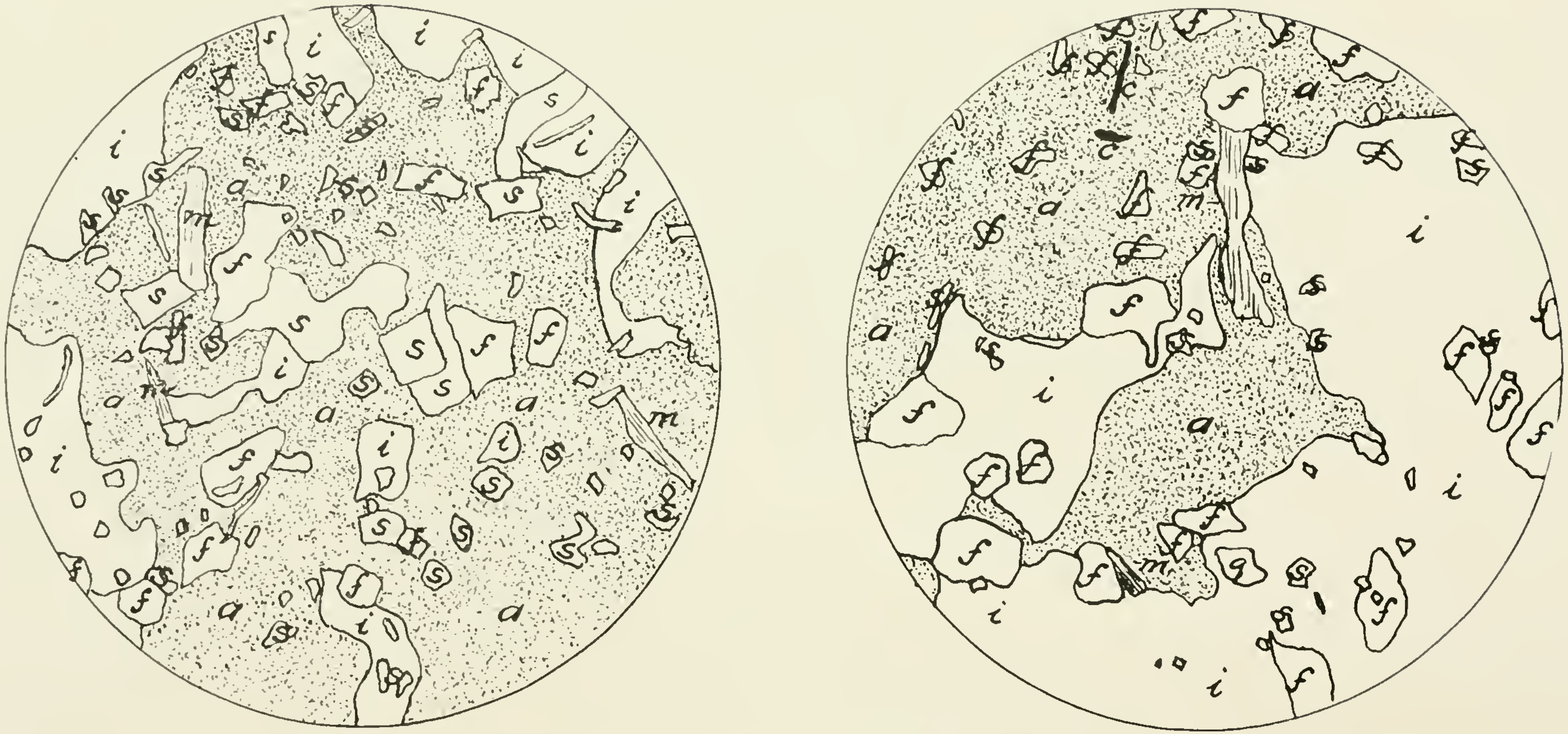
Thin section of No.3, X 54 diameters

Nicols crossed

Micrometer scale

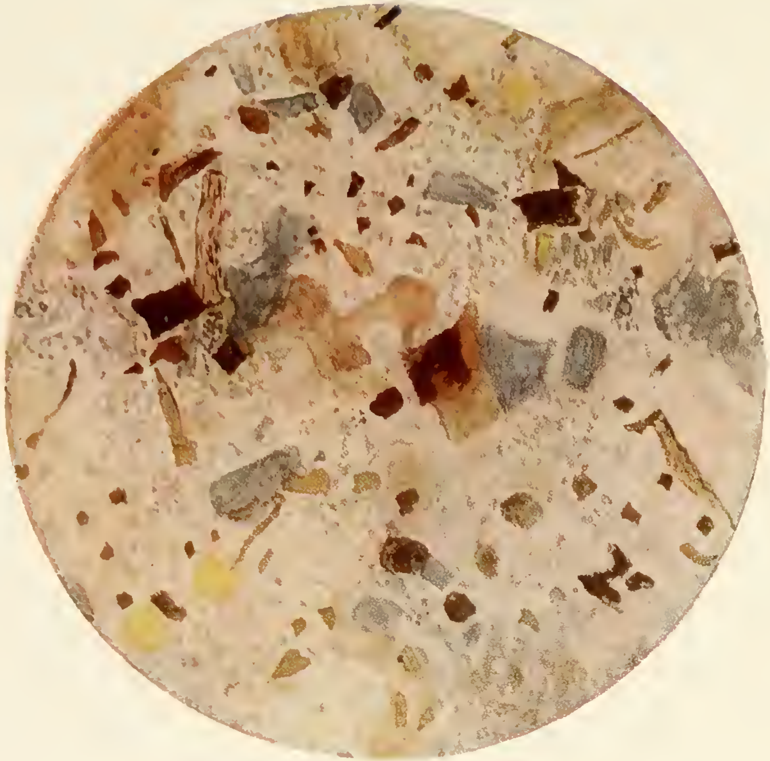


KEY TO SECTIONS 5 AND 6

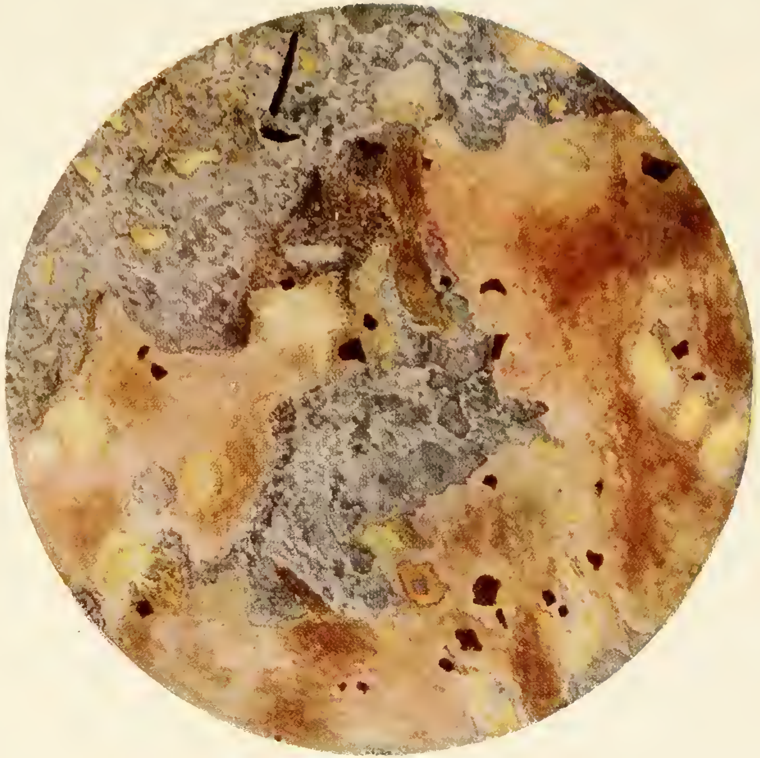


a. Areas of aggregate polarization, mostly orthoclase.
c. Grains of coal.
f. Grains of orthoclase feldspar.
i. Areas clouded by iron mist.
m. Shreds of mica, biotite.
q. Grain of quartz.
s. Areas and grains of iron ore, grains probably siderite.

PLATE III.



Thin section of No. 5, X 87 diameters

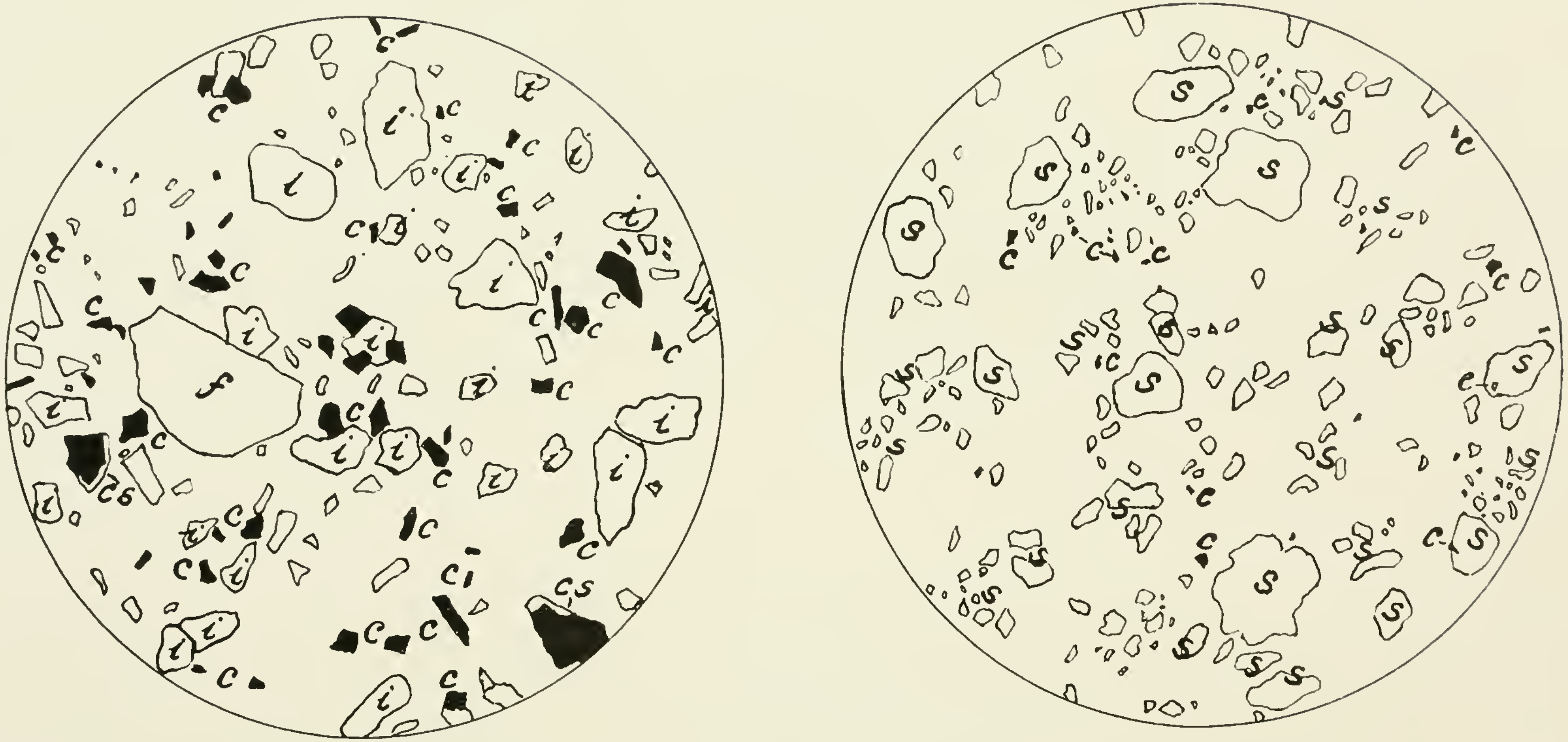


Thin section of No. 6, X 54 diameters

Nicols crossed

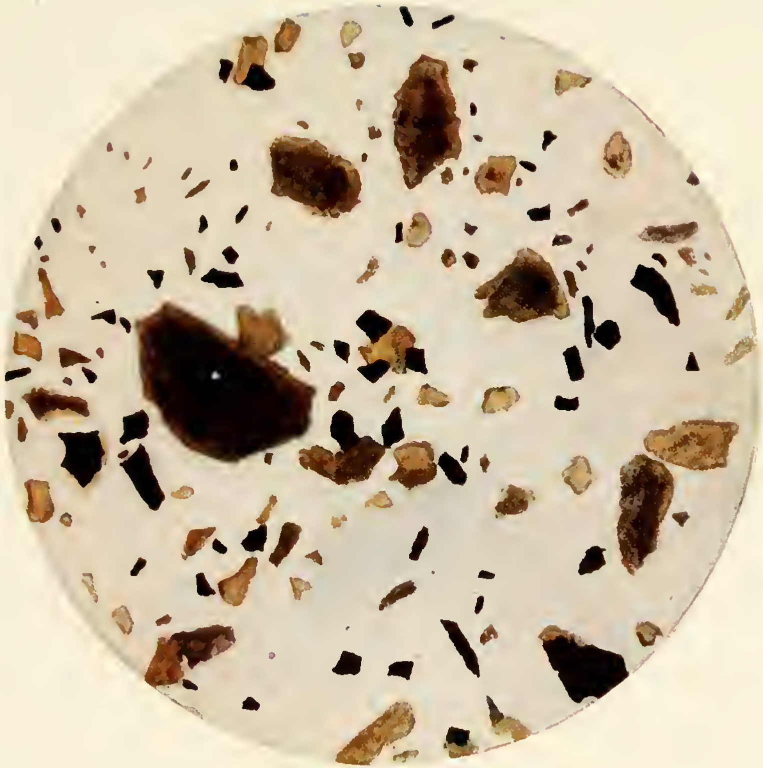
Micrometer scale

KEY TO SECTIONS 1 AND 3

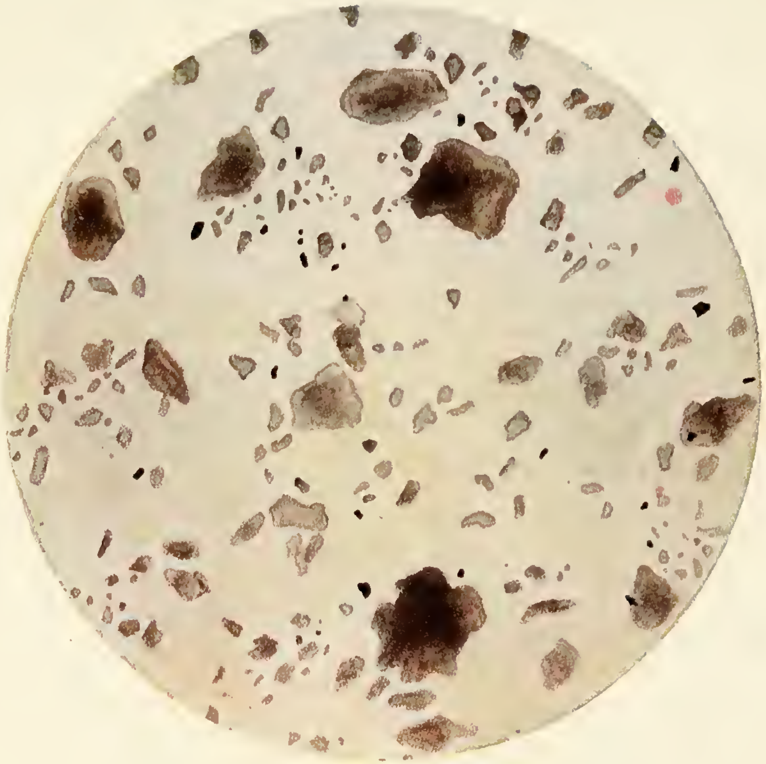


c. Grains of coal.
i. Grains of shale stained by iron.
s. Grains of drab shale.
f. Thin flake of shale.
cs. Coal with adhering shale.

PLATE IV.



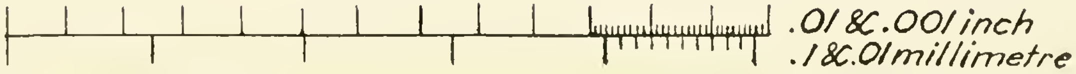
60-mesh dust of No. 1, X 23 diam.



60-mesh dust of No. 3, X 23 diam.

Transmitted light

Micrometer scale



PROCEEDINGS OF THE COLORADO SCIENTIFIC SOCIETY
VOL. X. pp: 279-414.

REPORT OF THE COMMITTEE ON UNIFORM MINE ACCIDENT LAWS.

Read at the meeting of the Society, May 3, 1913

To the President and Members of the Society:

Your committee appointed November 2nd, 1912, to make suggestions regarding a uniform law for the prevention of mine accidents, desire to submit the result of their work as follows:

The Committee as originally appointed consisted of Messrs. Charles A. Chase, George E. Collins, Charles W. Comstock, Victor G. Hills and Arthur J. Hoskin; Mr. Hoskin acting as Secretary. After two or three meetings Mr. Hoskin left the State for an indefinite period, and his place was filled by Mr. E. Lyman White, who thereafter acted as secretary.

The original Committee on Uniform Mine Accident Laws was appointed at the Denver meeting of the American Mining Congress in November, 1906; the same Committee being commissioned to report also to the American Institute of Mining Engineers and the Mining and Metallurgical Society of America. This Committee, consisting of Messrs. Walter Renton Ingalls, J. Parke Channing, James Douglas, J. R. Finlay and John Hays Hammond, made a report dated September 1, 1910; which report contains a draft for a proposed Mine Accident Law. Discussion, suggestions and criticisms by other bodies interested in mining, and from mining men in general, were invited by the original committee; and at the request of its chairman the Colorado Scientific Society's Committee was appointed.

The original committee's report was published in the Bulletins of the American Institute of Mining Engineers and the Mining and Metallurgical Society of America, and in the mining journals generally, about November, 1910; and thus has become familiar to all interested in the subject. On this account we have followed the order of the original committee's draft report, and have made our report in the form of parallel columns, giving both texts in full.

GENERAL COMMENTS.

In order intelligently to frame measures for the prevention of mine accidents, the prime prerequisite is to understand the causes which produce them. In the opinion of this Committee the principal cause, and that which results in our accident rate being so largely in excess of that in Europe, is lack of discipline. On the other hand it is neither desirable nor possible to revert to the social conditions which have facilitated superior discipline in Europe, at the expense of individual initiative. The best available means of increasing discipline under our conditions is therefore to improve the status of those in authority, and consequently the degree of respect which will be paid to the rules which it is their function to formulate or enforce. We therefore urge special consideration of the moderate changes which we suggest in the proposed qualifications for mine inspectors and mine superintendents.

We have referred above to the undesirability of interfering with individual initiative. This is particularly necessary in the case of typical vein-mines, where the workings are usually scattered, and the number of men in each working place small. Under such conditions it is imperative that reliance be placed, in great measure, on rules which the individual workman must apply for himself, rather than on minute supervision from outside.

Furthermore, we desire to lay particular stress on the fact that the majority of mines are small and employ few men; and moreover that it is the small mines which most urgently need inspection and regulation. Laws and rules should therefore be framed with special care to ensure that they are fairly and practically applicable to small mines.

We are not convinced that it is necessarily impossible to secure the passage by State Legislatures of any provision for the punishment of employees violating the law, and we have suggested the insertion of several clauses embodying this feature.

We think that unnecessary detail in the provisions of the Act is undesirable and to be avoided. We recommend that, as far as possible, discretion be left to the Inspector of Mines.

We have considered it essential that some provision, however moderate in scope, should be framed with a view to protecting miners from the conditions causing silicosis.

In certain cases we observe duplicate provisions in several sections dealing with the same subject, which we think unwise, as likely to lead to conflicting interpretation.

Finally, we wish to emphasize the desirability of securing uniformity of law throughout the mining States. This presupposes that the utmost care be taken to avoid incorporating in the law any provisions which would be impossible or undesirable in special cases, or even work a great hardship in such cases. Provisions which cannot be enforced, or which apparently are unreasonable or impracticable, tend to create disrespect for the law itself.

We have been careful to eliminate anything which might reasonably be considered a "counsel of perfection." Our recommendations, therefore, should be considered, not as embodying all the provisions for safety that we think desirable, but rather such a minimum as, in our opinion, may safely be insisted on in all cases, and properly incorporated in the law.

The above general principles have largely guided this Committee in its study of the proposed Code, and in the suggestions formulated for its improvement.

(A Reprint of the Report of the Original Committee published in 1910)

AN ACT.

RELATING TO METALLIFEROUS MINES IN THE STATE OF .... AND TO PROVIDE FOR THE HEALTH AND SAFETY OF PERSONS EMPLOYED IN AND ABOUT THE SAME.

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Sec. 1. DEFINITION OF TERMS.

The terms of this Act shall apply to all quarries and metalliferous mines in the State of ——— employing more than 10 persons in any period of 24 hours.

MINE. The term "Mine" when used in this Act is intended to include quarries and prospect openings; and to mean any and all parts of the property of a mine, prospect, quarry and mining plant on the surface or underground, which contribute directly or indirectly to the mining or handling of minerals. But the term "Mine" shall not apply to collieries.

OPERATOR. The term "Operator" when used in this Act means the person, firm or body corporate in immediate possession of any mine and its accessories as owner or lessee thereof, and as such responsible for the condition and management therof.

SUPERINTENDENT. The term "Superintendent," when used in this Act, means the person who shall have the immediate supervision of the mine.

MINE FOREMAN. The term "Mine Foreman," when used in this Act, means a person who is charged, at any one time, with the general direction of the underground work.

INSPECTOR AND DEPUTY. The term "Inspector," when used in this Act, signifies the State Inspector of Mines, and the terms "Deputy" and "Deputy Inspector," when used in this Act, means a State Deputy Inspector of Mines.

EXCAVATIONS OR WORKINGS. The words "Excavations" and "Workings," when used in this Act, signify any or all parts of a mine, excavated or being excavated, including shafts, tunnels, entries, galleries, open cuts and all working places, whether abandoned or in use.

SECTION 1. DEFINITION OF TERMS.

The terms of this Act shall apply to all quarries and metalliferous mines in the State of————————

Sec. 1. COMMENT:—We think that there should not be the limit of ten persons. Relatively small mines need inspection and regulation more than large ones. Old mines, with extensive workings, but now being operated by a tributer employing less than ten men, need the attention of the Inspector quite as much as any other mines. Hence our deletion of this limitation.

MINE. The term "Mine" when used in this Act is intended to include metalliferous mines, quarries, prospect openings, all other underground openings which contribute directly or indirectly to the production of economic minerals, and adits or tunnels driven for railroads or for water supply; and to mean any and all parts thereof. But the term shall not apply to collieries.

OPERATOR. The term "Operator," when used in this Act, means the person, firm or body corporate in immediate possession of any mine and its accessories as owner or lessee thereof, and as such responsible for the condition and management thereof.

SUPERINTENDENT. The term "Superintendent," when used in this Act, means the person who shall have the immediate supervision of the mine.

FOREMAN. The term "Foreman," or "Mine Foreman," when used in this Act, means a person who is charged, at any one time, with the general direction of the underground work.

INSPECTOR AND DEPUTY. The term "Inspector," when used in this Act, signifies the State Inspector of Mines, and the term "Deputy" or "Deputy Inspector," when used in this Act, means a State Deputy Inspector of Mines.

EXCAVATIONS OR WORKINGS. The words "Excavations" and "Workings," when used in this Act, signify any or all parts of a mine, excavated or being excavated, including shafts, tunnels, entries, galleries, open cuts and all working places, abandoned or in use.

Sec. 2. OFFICE OF INSPECTOR OF MINES.

The office of Inspector of Mines for the State of ——— is hereby created.

The Governor of the State, by and with the advice and consent of the Senate, shall appoint such Inspector of Mines. The Inspector of Mines shall be at least 30 years of age, a citizen of the United States, a resident of this State for at least one year previous to his appointment, and shall be practically engaged in metalliferous mining, and shall have had at least 10 years' experience in underground mining in the State of————. The Inspector of Mines (but not the deputy inspectors) must have been for at least 5 years in charge of a mine, employing fifty or more men underground to be qualified for such office. He shall receive as full compensation for services a salary of Dollars ($) per annum. He shall hold his office for a term of four years (the first term beginning January , 19) unless sooner removed by the Governor, or until his successor is appointed and qualified; and in case of vacancy by death, removal, resignation or otherwise, the Governor shall fill such office, for the remainder of any such term of four years, by appointment.

SECTION 2. OFFICE OF INSPECTOR OF MINES.

The office of Inspector of Mines for the State of ———— is hereby created.

The Governor of the State, by and with the advice and consent of the Senate, shall appoint such Inspector of Mines, who shall be paid as full compensation for his services a salary of ————dollars per annum. He shall hold his office for a term of ———— years, unless sooner removed by the Governor, or until his successor is appointed and qualified. The Governor may at any time remove said Inspector of Mines for incompetency, neglect of duty or malfeasance in office. In case of vacancy by death, removal, resignation or otherwise, the Governor shall fill such office, for the remainder of any such term of ———— years, by appointment.

(2.) COMMENT:—We fail to discover why a portion of the qualifications for the Inspector should be placed in a separate isolated section (Sec. 4). It seems to us that the matter of Sections 2 and 4 should be considered together, and the substance of Section 4 inserted as a paragraph in Section 2, or else that Section 2 should contain only the first and last portions of that section as printed, and that all of the qualifications should be grouped together in another section immediately following. We have written the matter in the latter form; but the order might be made the same if all were included in one section.

Further:—We consider the requirement that the whole ten years of experience shall be in the state as quite unreasonable, for a native American citizen may readily and frequently have had a portion of his mining and management experience in other states or in foreign countries, and be none the less qualified in every sense; while on the other hand a requirement that one or more years of the exprience shall be in the particular state in question is reasonable, and would naturally be expected.

Considering the vast number of small metalliferous mines which employ only from ten to 50 men underground, and considering the amount of mining which can be done with modern machinery by ten men on the underground force, we believe that when the mine is engaged in actual ore production the requirement of the employment of 50 men is too high; but, on the other hand, we regard the experience of mining (as defined in this act) or of management of underground work pertaining to drainage, transportation, or development, though employing "50 or more men underground," but not working in ore, as incompetent to supply the experience needed for this office. We consider breaking ore safely, stope timbering, stope ventilation, etc., to be most important experience to qualify for this office.

We think that the term of office must be left blank, to be filled by each State to correspond with its individual laws.

Sec. 3. DEPUTY INSPECTOR OF MINES.

The office of Deputy Inspector is hereby created. The Inspector of Mines is hereby authorized and directed forthwith, upon the entering of the duties of his office, to appoint ——— Deputy Inspectors, who shall each receive a salary payable at the rate of $——— per annum while holding such office. All Deputy Inspectors appointed under the provisions of this Section shall be subject at any time to removal by the Inspector. The Inspector shall also appoint hereafter such additional deputies as the Legislature may provide, who shall, when so appointed by the Legislature, be in all ways subject to the provisions of this section. In case of vacancy in the office of any deputy inspector caused by death, removal or otherwise, the Inspector of Mines shall forthwith fill such vacancy. The qualifications of all deputy inspectors shall be the same as those required in the case of the Inspector of Mines, as set forth in Section 2 of this Act; excepting, however, that such deputy inspector shall have been for two years in charge of a mine in the United States of America employing at least twenty-five men underground. All Deputy Inspectors shall perform duties as required by this Act, and shall be under the direct control and direction of the Inspector of Mines. In the absence or disability of the Inspector of Mines, any deputy designated by him may act with like authority as the Inspector of Mines. In the case of a vacancy in the office of the Inspector of Mines, the deputy longest in office present, shall act as such Inspector, until such vacancy has been filled.

[See our Sections 4 and 5.]

Sec. 4. QUALIFICATIONS AND POWERS OF INSPECTORS.

No person shall be appointed to the office of Inspector or Deputy Inspector, nor be qualified to hold the office of Inspector or Deputy Inspector, while an employee, director or officer of any mining, milling or smelting company; or while directly or indirectly connected with any mining company or co-partnership operating in this State, either as stockholder, partner, or in any other capacity; or while engaged in private practice as a consulting engineer. The Inspector and each deputy must devote his entire time to the duties of their respective offices; and it shall be unlawful for the inspector, or any deputy, to be otherwise employed by the State of ——— or to act directly or indirectly, for or on behalf of any candidate for public office, or for any political party, or receive compensation either directly or indirectly from any candidate for public office or from any political party in the State during the terms of such Inspector or Deputy Inspector. Failure to observe the provisions of this section shall render the inspector liable to immediate removal from office by the Governor without further cause shown; and such failure shall render any deputy inspector liable to immediate removal by the Inspector of Mines, without further cause shown; and the Governor and Inspector of Mines are hereby authorized and empowered to make removals in such cases.

SECTION 3. (4). QUALIFICATIONS OF INSPECTOR OF MINES.

The Inspector of Mines shall be a citizen of the United States, and a resident of this State for at least one (1) year previous to his appointment. He shall be not less than thirty (30) nor more than sixty (60) years of age, of good health and physically fit to traverse all mine workings. He shall have had at least ten (10) years' experience in underground mining, of which at least one (1) year shall have been in this State. He shall have been for an aggregate period of not less than five (5) years in responsible charge of a mine or mines employing twenty-five (25) or more men underground, or of a producing mine or mines employing ten (10) or more men underground. He shall hold a degree as graduate from some recognized technical school, or he shall produce evidence that he has otherwise acquired an equivalent technical training.

No person shall hold the office of Inspector of Mines while an employee, director or officer of any mining, milling or smelting company, or while engaged in private practice as a consulting engineer. He must devote his entire time to the duties of his office; and it shall be unlawful for the Inspector to be otherwise employed by this State, or to act, directly or indirectly, for or on behalf of any candidate for public office, or for any political party, or to receive compensation either directly or indirectly from any person or organization other than the State, during his term of office. Failure to observe the provisions of this section shall render the Inspector liable to immediate removal from office by the Governor without further cause shown; and the Governor is hereby empowered and directed to make removal in such case.

(4.) (Our Section 3) COMMENT:—The provision that no man shall hold the office of Inspector of Mines while "directly or indirectly connected with any mining company or co-partnership operating in this State, either as stockholder, partner or in any other capacity," seems an attempt to secure purity of motive and singleness of purpose at extraordinarily high cost in narrowing the field of selection; in that men who may be desirable may not feel warranted in severing important business connections to accept

a temporary position: even worse, the best men, who could perhaps take the place by virtue of auxiliary income, are barred.

The field of choice, thus narrowed, must consist of those men who have lacked training, disposition or courage to engage in mining with their own money, and to accept it as a life work. There may be good reason why a man who is heart and soul in the work may not have his own money in mining; but, in the long run, the academic miner will more often be selected from the restricted field, and he is not best.

Granted equal training and like qualities of mind and heart, the man who has his own money in the industry and who will keep it in will carry greater authority and dignity to the office.

While we realize that the term "technical graduate" is likely to frighten the average legislator, we believe that there is a recognized tendency toward higher standards, and that this thing is worth trying for.

A minority of the committee believe that a technical education, however desirable, is so far subordinate to executive ability and tact in qualification for this position that it should not be put into the statute; and further, admitting the desirability of securing the best educated men possible for this position, still think it not best to attempt to put the words "technical education" into a statute. However, if a competitive examination should be required to qualify for this office, which may be the case in some States, this question would be happily adjusted.

[See Page 288.]

SECTION 4. (3). OFFICE OF DEPUTY INSPECTOR OF MINES.

The office of Deputy Inspector of Mines for the State of ———— is hereby created.

The Inspector of Mines is hereby authorized and directed to appoint one or more Deputy Inspectors, for whose official acts he shall be responsible; and he may revoke such appointment at his discretion.

Each Deputy Inspector shall be paid, as full compensation for his services, a salary of————dollars per month.

The total amount which may be expended for salaries of Deputy Inspectors in any calendar year is hereby limited to ————————dollars.

Sec. 4. COMMENT:—The above changes in the method of appointment and term of office of Deputy Inspectors are suggested because in some States it may be more convenient to appoint a larger number of deputies, during certain seasons of the year, rather than a less number to serve throughout the year. Our suggestion follows to some extent the Colorado law which provides for the appointment by the State Engineer of his assistants, which law has been found satisfactory in practice.

SECTION 5. (3) QUALIFICATIONS OF DEPUTY INSPECTOR OF MINES.

The Deputy Inspector of Mines shall have the same qualifications as those required in the case of the Inspector of Mines, as set forth in Section 3 of this Act; excepting, however, that such Deputy Inspector need have had only five (5) years' experience in underground mining, of which at least one (1) year shall have been in this State, and have been for one (1) or more years in responsible charge of a producing mine or mines employing at least ten (10) men underground.

All Deputy Inspectors shall perform duties as required by this Act, and shall be under the immediate control and direction of the Inspector of Mines.

The Inspector of Mines shall designate one Deputy Inspector as Chief Deputy Inspector, who in the absence or disability of the Inspector shall act with like authority as the Inspector of Mines, and in case of a vacancy in the office of Inspector of Mines shall act as such Inspector until such vacancy shall have been filled.

Sec. 5. SALARY AND EXPENSES.

All reasonable and necessary expenses actually incurred by the Inspector and by any deputy in the performance of their duties, for traveling expenses, clerk-hire, postage, stationery, printing and disbursements incidental and reasonable to the office of Inspector, or of Deputy Inspector, shall be paid by the State Treasurer upon the warrant of the Comptroller* issued upon proper vouchers therefor, when approved by the Inspector of Mines, but such expenses, together with the salaries of the Inspector and his deputies, shall not be incurred in excess of appropriations by the Legislature. The salaries of Inspector of Mines and of all deputy inspectors shall be paid as the salaries of other State officers are paid.

Sec. 6. INSPECTORS SHALL BE ALLOWED ALL LEGAL EXPENSES.

The Inspector may employ counsel to represent him, or any deputy, or to assist in the prosecution of actions or proceedings brought under the provisions of this Act.

In addition to the expenses allowed to the Inspector, as set forth in Section 5 of this Act, he shall be allowed all necessary expenses and reasonable counsel fees actually incurred in enforcing the several provisions of this Act in the respective Courts of this State, and the same shall be paid by the State Treasurer on warrants drawn by the Comptroller* after auditing the same; all such claims and expense accounts shall be presented and passed by the Inspector, and approved by the Court before which such proceedings were instituted. In the event of any costs being finally taxed against the State in any suit in which the State, at the relation of the Inspector is either plaintiff or defendant, the same shall be approved by the Court, and audited and paid in like manner as such legal expenses are authorized to be paid as aforesaid.

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*Each State will substitute the title of the proper official according to its own system.

SECTION 6 (5). SALARY AND EXPENSES.

All reasonable and necessary expenses actually incurred by the inspector or by any deputy in the performance of their duties, for traveling expenses, clerk-hire, postage, stationery, printing and disbursements incidental and reasonable to the office of inspector, or of deputy inspector, shall be paid by the State Treasurer upon the warrant of the————————[proper state officer] issued upon proper vouchers therefor, when approved by the Inspector of Mines, but such expenses, together with the salaries of the inspector and his deputies, shall not be incurred in excess of appropriations by the Legislature. The salaries of Inspector of Mines and all Deputy Inspectors shall be paid as the salaries of other State officers are paid.

NOTE.—This is original Section 5 with slight change.

SECTION 7. (6). LEGAL SERVICES.

The Inspector shall be entitled to the counsel and services of the Attorney General of this State, who shall prosecute any legal proceeding which may, in the judgment of the Inspector, be necessary for the enforcement of the provisions of this Act, or of any other Act which the Inspector is, or may hereafter be required to enforce, and shall defend the Inspector in any legal proceeding which may be directed against him in his official capacity; *provided, however*, that all the expenses of any such legal proceeding shall be paid from the State funds appropriated to the office of Inspector of Mines.

COMMENT:—We believe that the employment of independent counsel by different bureaus and executive offices is unbusinesslike, and that it tends to confusion in the administration of laws.

It would seem much better to put all the attorneys who represent the State, or any department of its administration, under one general direction. Such direction is naturally that of the Attorney General. This makes for efficiency, consistency, and a minimum of expense in all matters demanding legal counsel or procedure.

Experience in Colorado shows clearly the inadvisability of permitting individual State officers or departments to employ legal counsel, apart from and independent of the regular legal department of the State. Such a practice has been found to result in inefficiency and waste of public funds.

Sec. 7. OFFICE AND RECORDS OF INSPECTOR OF MINES.

The inspector of mines shall be provided with a properly furnished office in the State House in ———— in which he shall keep a record of all mines in the State, a record of all mines examined either by the inspector or his deputies, showing the dates of such examinations, the condition in which the mines so examined were found, with particular reference to the safety, ventilation and sanitary conditions of each mine so examined, the manner and method of working, all violations of the provisions of this Act found, if any, the action taken thereon, and the result of such action, together with recommendations made in case of each mine examined by the inspector or any deputy; and any other data or information pertaining to his office and acquired during the carrying out of this Act. For the purpose of aiding the inspector in making up such data it shall be the duty of each deputy to transmit from time to time, or upon request from the inspector, a complete record of all mine examinations made by such deputy, and an itemized statement of his work as such deputy in such form and covering such detail as the inspector shall in his opinion deem necessary.

All documents, plans, books, memoranda, notes and other material pertaining to the office of the Inspector of Mines, or of any Deputy Inspector, shall be the property of the State, and shall be delivered by the said inspector, or by such deputy inspectors, to their successors in office. The inspector may at any time call for all or any papers, documents, plans, books, memoranda, notes or other material in the hands of any deputy, who shall deliver same to said inspector upon call.

SECTION 8. (7). OFFICE AND RECORDS OF INSPECTOR OF MINES.

The Inspector of Mines shall be provided with a properly furnished office in the State House in ———— in which he shall keep a record of all mines in the State, a record of all mines examined either by the inspector or his deputies, showing the date of each examination, the condition in which every mine so examined was found, with particular reference to its safety, ventilation and sanitary condition, the manner and method of working, all violations of the provisions of this Act found, if any, the action taken thereon, and the result of such action, together with recommendations made, and any other data or information pertaining to his office and acquired during the carrying out of this Act. For the purpose of aiding the inspector in making up such data it shall be the duty of each deputy to transmit from time to time, or upon request from the inspector, a complete record of all mine examinations made by such deputy, and an itemized statement of his work as such deputy in such form and covering such detail as the inspector shall in his opinion deem necessary.

All documents, plans, books, memoranda, notes and other material pertaining to the office of the Inspector of Mines shall be the property of the State, and shall be delivered by the inspector to his successor in office.

COMMENT:—We think that the Inspector of Mines should be the sole responsible head of his office; and that the law should not regard the deputies as being in custody of any papers, etc.

Sec. 8. REPORTS TO INSPECTOR OF MINES.

It is hereby made the duty of the operator of each and every mine within the State to forward to the inspector at his office, not later than the 20th day of January, in each year, a detailed report in writing, on a form prescribed by the inspector, showing the character of the mine, tonnage of ore produced during the previous year, ending December 31st, the average number of men therein employed during the year (the average number of men employed being computed by dividing the total number of shifts worked per man by the number of days the mine was worked), the number of days the mine was worked, the number of fatal and serious accidents during the year, and such other information relative to the workings, equipment, ventilation, sanitation, means of ingress and egress, shafts, tracking, supports, safety devices, storage of explosives, means taken to protect live and usual safety of men in relation to any of the requirements of this Act, as the inspector may, from time to time require. All such reports shall be filed in and become part of the records of the office of the Inspector of Mines. Blank forms for such reports shall be furnished by the State.

SECTION 9. (19) STATISTICAL REPORTS OF MINE INSPECTOR.

It shall be the duty of the Inspector of Mines, within three months after January 1st in each year, to make a report directed to the Governor and Legislature of this State, giving a statistical summary and report of the work of the Inspector and Deputy Inspectors of Mines during the previous year ending December 31st. Such report shall contain a statement showing the number of men employed in each mine in the State, stating separately the number of men employed above ground and underground, the number and nature of fatal and serious accidents occurring in each mine, the number of inspections made, complaints filed, inquests attended, mines ordered to be vacated, violations found and any other information deemed important and relevant by the Inspector of Mines, together with such recommendations as in the judgment of the Inspector of Mines are necessary or desirable to the carrying out of this Act and to insure the safety of the workmen employed within the mines, subject to the provisions of this Act. Copies of such report shall be published and distributed by and at the expense of the State as a public document.

(No change.)

SECTION 10. (8). REPORTS TO INSPECTOR OF MINES.

It is hereby made the duty of the operator of each and every mine within the State to forward to the inspector at his office, not later than the 20th day of January in each year, a detailed report in writing, on a form prescribed by the inspector, showing the character of the mine, the tonnage of ore produced during the previous year ending December 31st, the average number of men therein employed during the year (the average number of men employed being computed by dividing the total number of shifts worked by the number of days the mine was worked), the number of days the mine was worked, the number of fatal and serious accidents during the year, and such other information relative to the workings, equipment, ventilation, sani-

Provided, however, that in the case of any mine being operated for less than one year prior to December 31st in any year the operator in such event shall forward a report, in like manner, covering the period during which said mine was operated, and

Provided further, that in the event of the sale or lease of any mine during any year prior to December 31st, that then and in that event it shall be the duty of the owner or operator so selling, leasing or turning over such mine to a succeeding operator to supply to such succeeding operator a like report, as required in this section, covering the period of such former operations within said year; and it shall then and in that event become the duty of such succeeding operator to forward such report so turned over, together with said succeeding operator's report, for the period of said succeeding operator's operations, to the Inspector of Mines as aforesaid, not later than the 20th day of January in each year.

In all cases, occurring in or about any mine, of underground fires, breakage of ropes or other gear by which men are hoisted, or lowered, overwinding while men are being hoisted, or inrush of water from old workings, whether or not personal injury or disablement results, a report thereof, signed by the operator or superintendent must immediately be sent in writing to the inspector.

A failure, neglect or refusal to make such reports or to give such information as are provided for in this section, upon demand made in writing by the inspector, or by any of his deputy inspectors, shall constitute a misdemeanor and every such operator, or person in charge of such mine, or other person so failing, neglecting or refusing after written demand made as aforesaid shall be deemed guilty of a misdemeanor, and on conviction shall be fined for each offense not less than fifty dollars or more than two hundred dollars; and each separate failure, neglect or refusal after demand, as aforesaid, shall constitute a separate offense.

tation, means of ingress and egress, shafts, tracking, supports, safety devices, storage of explosives, means taken to protect lives and ensure safety of men in relation to any of the requirements of this Act, as the inspector may from time to time require. All such reports shall be filed in and become part of the records of the office of the Inspector of Mines. Blank forms for such reports shall be furnished by the State.

Provided, however, that in the case of any mine being operated for less than one year prior to December 31st in any year, the operator in such event shall forward a report, in like manner, covering the period during which said mine was operated, and

Provided further, that in the event of the sale or lease of any mine during any year prior to December 31st, it shall be the duty of the owner or operator so selling, leasing or turning over such mine to a succeeding operator to supply to such succeeding operator a like report, as required in this section, covering the period of such former operations within said year; and it shall become the duty of such succeeding operator to forward such report so turned over, together with said succeeding operator's report for the period of said succeeding operator's operations, to the Inspector of Mines as aforesaid, not later than the 20th day of January in each year.

A failure, neglect or refusal to make such reports or to give such information as are provided for in this section, upon demand made in writing by the Inspector, or by any of his deputy inspectors, shall constitute a misdemeanor, and every such operator, or person in charge of such mine, or other person so failing, neglecting or refusing after written demand made as aforesaid shall be deemed guilty of a misdemeanor, and on conviction shall be fined for each offense not less than fifty dollars or more than two hundred dollars; and each separate failure, neglect or refusal after demand, as aforesaid, shall constitute a separate offense.

COMMENT:—We have deleted the fourth paragraph from this section and inserted it in Section 17 (16) entitled **Accidents**, with other mine accident provisions. Otherwise, excepting for verbal emendations, this Section is unchanged.

Sec. 9. DESIGNATION FOR SERVICE OF NOTICES.

Every operator of any mine within the provisions of this Act, shall, within sixty days after the passage of this Act, file or cause to be filed in the principal office of the Inspector of Mines a designation, duly verified, by such operator, designating a person upon whom all notices, warnings or processes, required to be served under the provisions of this Act, may be served in this State. The person so designated must have an office, place of employment or place of business within ten miles of the principal place of business of such operator within the State, and such designation shall give the office, place of employment or place of business of such person so designated. Such designation shall be accompanied by the written consent of the person so designated, and shall continue in force until revoked by the death or removal of the person so designated, or until revoked by an instrument in writing designating in like manner some other person upon whom such notices or processes may be served, or until the filing in such office of a written revocation of said consent executed by the person so designated. If the person so designated dies or removes beyond ten miles of the place of business of such operator, or files a revocation of his consent, the operator must, within thirty days thereafter, designate in like manner some other person upon whom such notices or processes may be served within this State.

Services upon such designated person of notices, warnings or processes shall, in all cases arising under this Act, be deemed service upon such operator;

Provided, however, that nothing herein contained shall be construed to prevent the said operator in person, or its officers or agents, if said operator be a corporation, or any employee of such operator, from being so designated. A failure on the part of any operator to carry out the provisions of this section shall be deemed a violation of this Act.

SECTION 11. (9) DESIGNATION FOR SERVICE OF NOTICES.

Every operator of any mine within this State shall, within sixty days after the passage of this Act, file or cause to be filed in the principal office of the Inspector of Mines a designation, duly verified by such operator, designating a person upon whom all notices, warnings or processes, required to be served under the provisions of this Act, may be served in this State. The person so designated must have an office, place of employment or place of business within the State, and such designation shall give the office, place of employment or place of business of such person so designated. Such designation shall be accompanied by the written consent of the person so designated, and shall continue in force until revoked by the death or removal of the person so designated, or until revoked by an instrument in writing designating in like manner some other person upon whom such notices or processes may be served, or until the filing in the office of the Inspector of Mines of a written revocation of said consent executed by the person so designated. If the person so designated dies or removes beyond the limits of the State, or files a revocation of his consent, the operator must, within thirty days thereafter, designate in like manner some other person upon whom such notices or processes may be served within this State.

Service upon such designated person of notices, warnings or processes shall, in all cases arising under this Act, be deemed service upon such operator;

Provided, however, that nothing herein contained shall be construed to prevent the said operator in person, or any of its officers or agents, if said operator be a corporation, or any employee of such operator, from being so designated. A failure on the part of any operator to carry out the provisions of this section shall be deemed a violation of this Act.

COMMENT:—The provision of an agent within ten miles of the principal place of business seems illogical (we assume that in many cases the principal place of business is the mine itself), in that it specifies a limit of radius that is often impractical and sometimes impossible in the high mountain or desert sections during periods of inactivity of mines so situated;

Sec 10. SECRECY OF RECORDS.

The inspector or any deputy inspector, or any person employed by such inspector or deputy inspector, or any person having access to the papers filed in the office of said inspector, or in the office of any deputy inspector, shall not make public or reveal to any person or persons either orally or in writing, all or any part of the contents of any report, complaint or document filed in the office of the inspector of mines of this State, or in the office of any of his deputy inspectors, or reveal or make public to any person or persons any knowledge or information in regard to the safety, or physical or financial condition of any mine, mining rights, prospect or mining company or concern obtained by any of the aforesaid inspector, deputy inspectors or employees, while in the exercise of his or their official duties. Nothing herein contained, however, shall be construed to prevent any inspector or deputy inspector, or any clerk, or employee of such inspector or deputy inspector from making official reports to the Governor or Legislature of this State, to the inspector of mines, or to any deputy inspector, or from giving evidence in any Court of Justice in this State in discharge of his official duty. An inspector of mines, or any deputy inspector or mines, or any employee or clerk who violates any of the provisions of this section of this Act, shall be guilty of a misdemeanor and shall be punished upon conviction by a fine or not more than $500, or by imprisonment of not more than one year, or both; and shall also be dismissed from his office or employment.

while it avoids the larger towns and cities, which are the natural seats of the companies themselves in the case of domestic corporations, and of the representatives of foreign corporations. There is better promise of permanency of agency when these more favorable places are permitted.

SECTION 12. (10). SECRECY OF RECORDS.

The inspector or any deputy inspector, or any person employed by such inspector or deputy inspector, or any person having access to the papers filed in the office of said inspector, or in the office of any deputy inspector, shall not make public or reveal to any person or persons, either orally or in writing, all or any part of the contents of any report, complaint or document filed in the office of the Inspector of Mines of this State, or in the office of any of his deputy inspectors, or reveal or make public to any person or persons any knowledge or information in regard to the safety, or physical or financial condition, of any mine, mining right, prospect or mining company or concern, obtained by any of the aforesaid inspector, deputy inspectors or employees, while in the exercise of his or their official duties. Nothing herein contained, however, shall be construed to prevent any inspector or deputy inspector, or any clerk, or employee of such inspector or deputy inspector, from making official reports to the Governor or Legislature of this State, to the Inspector of Mines, or to any Deputy Inspector, or from giving evidence in any Court of Justice in this State in discharge of his official duty. An inspector of mines, or any deputy inspector of mines, or any employee or clerk, who shall violate any of the provisions of this section of this Act, shall be guilty of a misdemeanor, and shall be punished upon conviction by a fine of not more than $500, or by imprisonment of not more than one year, or both; and shall also be dismissed from his office or employment.

(No change.)

Sec. 11. DUTIES OF INSPECTORS—INSPECTION—POWERS.

It shall be the duty of the Inspector of Mines by himself or by deputy to visit at least once every two months every mine in the State employing 50 or more men underground; and every other mine at least once every year and oftener if in his opinion the safety of the men employed within the mine so requires; and to inspect, inquire and examine into the operation, workings, timbering, safety appliances, machinery, sanitation, ventilation, means of ingress and egress, means taken to protect the lives and insure the safety of the miners, together with the cause of accidents and accidental death therein, and in general, to inspect and ascertain what means are taken to comply with the provisions of this Act. For the purpose of making such inspection and ascertaining facts in connection with such examination and inquiry, the inspector, or his deputy, shall have full power and authority at all hours to enter and examine any part of any mine or mining plant within this State, or any part of the workings thereof. All operators and their employees shall render to the inspector or his deputy, such assistance as may be necessary to enable the inspector or his deputy to make such examination.

For the purpose of ascertaining facts in connection with any inspection, inquiry or examination, the said inspector, or any deputy, shall have full power to compel the attendance of witnesses by subpoena, and to take depositions, to administer oaths and to examine, cross-examine and take testimony of such persons as may be deemed necessary for the information of the inspector or his deputies. Any person refusing to obey a subpoena issued by the inspector, or by any deputy, or any person who shall wilfully in any manner hinder or obstruct the inspector, or any of his deputies, in the performance of his or any of their duties, under this Act, shall be guilty of a misdemeanor. Any witness appearing before the inspector, or before any of his deputies, in response to a subpoena so issued, who shall knowingly and wilfully testify falsely to any material matter, shall be deemed guilty of perjury, and upon conviction as by law provided, shall be punished for perjury.

SECTION 13. (11). DUTIES OF INSPECTORS—INSPECTION—POWERS.

It shall be the duty of the Inspector of Mines, by himself or by deputy, to visit at least once every six months every mine in active operation in the State, and to inspect, inquire and examine into the operation, working, timbering, safety appliances, machinery, sanitation, ventilation, means of ingress and egress, means taken to protect the lives and insure the safety of the employees, together with the cause of accidents and accidental death therein, and in general, to inspect and ascertain what means are taken to comply with the provisions of this Act. For the purpose of making such inspection and ascertaining facts in connection with such examination and inquiry, the inspector, or his deputy, shall have full power and authority at all hours to enter and examine any part of any mine or mining plant within this State, or any part of the workings thereof. All operators and their employees shall render to the inspector or his deputy such assistance as may be necessary to enable the inspector or his deputy to make such examination.

For the purpose of ascertaining facts in connection with any inspection, inquiry or examination, the said inspector, or any deputy, shall have full power to compel the attendance of witnesses by subpoena, and to take depositions, to administer oaths and to examine, cross-examine and take testimony of such persons as may be deemed necessary for the information of the inspector or his deputies. Any person refusing to obey a subpoena issued by the inspector, or by any deputy, or any person who shall wilfully in any manner hinder or obstruct the inspector, or any of his deputies, in the performance of his or any of their duties under this Act, shall be guilty of a misdemeanor. Any witness appearing before the inspector, or before any of his deputies, in response to a subpoena so issued, who shall knowingly and wilfully testify falsely to any material matter, shall be deemed guilty of perjury, and upon conviction as by law provided, shall be punished for perjury.

Sec. 12. DANGEROUS MINES—DUTIES OF INSPECTORS.

Whenever the inspector shall find any mine, or part of any mine, in an unsafe condition, by reason of any violation of any of the rules or provisions of this Act, or in a condition dangerous or detrimental to the life or health of those employed therein, for the same reason or by reason of defects in timbering, mining, ventilation or sanitation, it shall be the duty of the inspector at once to serve or cause to be served a notice in writing upon the operator of such mine, and such notice shall set forth in detail the nature and extent of the defects which render the mine or part of the mine unsafe, dangerous, or detrimental to the life or health of those employed therein, together with the point or place in the mine, or in the workings of the mine, where such defects exist, and such notice shall require such necessary changes to be made in such mine or part of the mine without delay, and within a specified time in the discretion of the inspector, to make the same conform to the provisions of this Act.

If it appears from a re-examination of the mine by the inspector, or a deputy inspector, that such necessary changes have not been made within the time specified in such notice, and that the mine or part of the mine is still in a condition dangerous to life or health, and in the opinion of the inspector it is necessary for the safety of the life or health of the employees in such mine or part of the mine, that the same be vacated, it shall be the duty of the inspector forthwith to institute an action for an injunction in any court of competent jurisdiction, in the name of the State, at the relation of the inspector, to restrain the operation and working of said mine, or part of said mine, and the permitting of employees therein for purposes other than to remedy the defects complained of, until the provisions of this law are complied with, and the said mine, or part of the mine, made safe for the em-

The Inspector of Mines is hereby authorized to institute, through the Attorney General of this State, legal proceedings appropriate to the enforcement of the provisions of this Act, or of any other Act which the Inspector of Mines is or may hereafter be required to enforce, or of any order issued by said Inspector of Mines or by any of his deputies under authority of law, whenever, in the judgment of the Inspector of Mines, such proceedings or any of them shall be necessary.

COMMENT:—We would not make the difference between large and small mines. A small mine does not require long to inspect, and needs the attention of an inspector even more than a large property.

The last paragraph has been added to make this section harmonize with Sec. 7 (6) entitled **Legal Services.**

SECTION 14. (12). DANGEROUS MINES. DUTIES OF INSPECTORS.

Whenever the Inspector shall find any mine, or part of any mine, in an unsafe condition, in consequence of violation of any of the rules or provisions of this Act, or in a condition dangerous or detrimental to the life or health of those employed therein, for the same reason or because of remediable defects in timbering, mining methods, ventilation or sanitation, it shall be the duty of the Inspector at once to serve or cause to be served a notice in writing upon the operator of such mine, setting forth in detail the precise nature and extent of the defects which render the mine or part of the mine unsafe, dangerous, or detrimental to the life or health of those employed therein, together with the point or place in the mine, or in the workings of the mine, where such defects exist, and such notice shall require such necessary changes to be made in such mine or part of the mine without delay, and within a specified time in the discretion of the inspector, to make the same conform to the provisions of this Act.

If the operator shall fail or refuse to make, or cause to be made, the changes required by such notice, within the time specified therein, it shall be the duty of the Inspector of Mines forthwith to order, in writing, the immediate discontinuance of work ployees therein; and the plaintiff in such action, without bond, and upon *ex parte* affidavits made by the inspector, or a deputy inspector, showing in detail the nature and extent of the defects which, in such affiant's opinion, render the mine, or part of the mine, unsafe or detrimental to life or health of those employed therein, and stating that such mine, or part of the mine, is, in the opinion of the affiant, in a condition dangerous to life or health, may procure a temporary injunction, pending the trial of said action, from any court or judge in vacation, if, in the opinion of the court or the judge, the facts warrant the granting of such temporary injunction, enjoining the operation and working of said mine, or part of said mine, and the permitting of employees therein, except for the purpose of remedying the defects complained of, until the further order of the Court.

Provided, however, that the defendants in such actions shall have the same opportunity to be heard, upon motion to vacate such temporary injunctions, as defendants have in any actions brought in this State in which temporary injunctive relief may be granted.

Sec. 13. REFUSING INSPECTION. PENALTY.

If the operator of any mine within the State shall fail, impede or refuse to permit such inspection, as is provided in Sections 11 and 12 of this Act, the inspector, or deputy, may file his affidavit setting forth such refusal before the judge of the Court in the County in which said mine is situated, either during the term of the Court or during vacation, and obtain an order directed to such operator, so refusing as aforesaid, commanding him to permit and furnish all necessary facilities for the entering, examination or inspection of such mine, or to be adjudged to stand in contempt of Court and punished accordingly.

in such mine, or part of mine, which is found to be in an unsafe condition as regards the life or health of those employed therein, and to refuse to permit any work whatever to be done therein, or any person to enter such mine or part of mine except for the purpose of remedying the defects specified in the above mentioned notice, or in other respects of putting such mine or part of mine in a safe condition. Such order shall be binding upon the operator of any mine in this State, and shall remain in full force and effect until specifically annulled, in writing, by the Inspector of Mines or his authorized deputy.

COMMENT:—The new draft of the last two paragraphs is made in order to harmonize with Sec. 7 (6), **Legal Services**, and Sec. 13 (11), **Duties of Inspectors—Inspection Powers.**

SECTION (13). Delete this Section; already provided for by our Section 13.

Sec. 14. RECORDS OF INSPECTION.

It shall be the duty of the inspector, or any deputy, after every inspection made of any mine or parts of any mine, as provided in this Act, to enter forthwith in a book to be kept at the mine, and designated as the "Record of Inspection," the portions of the mine so inspected, the nature of such inspection, and every illegal defect observed in the state and condition of the mine, machinery and appliances; but nothing contained in or omitted from such entry shall limit or affect the duty and obligation of the owner or operator of such mine under this Act. Such "Record of Inspection" shall be open at all reasonable times to the examination of the inspector, or any of his deputies, or to the examination of any persons employed in the mine.

Sec. 15. COMPLAINTS TO INSPECTORS.

Whenever the inspector receives a complaint in writing, signed by three or more persons employed in a mine, setting forth that the mine in which they are working is being operated contrary to law, and is dangerous in any respect to the health or lives of those employed therein, the inspector must in person, or by deputy, examine such mine as soon as possible. The names of the persons making such complaint shall be kept secret by the inspector, unless permission to disclose them be expressly granted by the persons making the complaint. *Provided, however*, that such complaint shall, in all cases, set forth the alleged violation of law observed, the nature of the danger existing at the mine, and the time when such violation and danger was first observed. If after such inspection, the inspector finds the conditions, in his opinion, dangerous to the health and lives of those employed therein, by reason of any violation of any of the provisions and rules of this Act, he shall serve, or cause to be served, a notice, setting forth fully the facts upon which his opinion is based, upon the operator or any person having charge of such mine, as

SECTION 15. (14). RECORDS OF INSPECTION.

It shall be the duty of the inspector, or any deputy, after every inspection made of any mine or part of mine, as provided in this Act, to enter forthwith in a book to be kept at the mine, and designated as the "Record of Inspection," the portions of the mine so inspected, the nature of such inspection, and every illegal defect observed in the state and condition of the mine, machinery and appliances; but nothing contained in or omitted from such entry shall limit or affect the duty and obligation of the owner or operator of such mine under this Act. Such "Record of Inspection" shall be open at all reasonable times to the examination of the inspector, or any of his deputies, or to the examination of any persons employed in the mine.

(No change.)

SECTION 16. (15.) COMPLAINTS TO INSPECTORS.

Whenever the inspector shall receive a complaint in writing, signed by three or more persons employed in a mine, setting forth that the mine in which they are working is being operated contrary to law, or is dangerous in any respect to the health or lives of those employed therein, the inspector in person, or by deputy, shall in his discretion examine such mine as soon as possible. The names of the persons making such complaint shall be kept secret by the inspector, unless permission to disclose them be expressly granted by every person making the complaint. *Provided, however*, that such complaint shall, in all cases, set forth the alleged violation of the law observed, the nature of the danger existing at the mine, and the time when such violation or danger was first observed.

If after such inspection the inspector finds the conditions, in his opinion, dangerous to the health and lives of those employed therein, by reason of any violation of any of the provisions and rules of this Act, he shall serve, or cause to be served, a notice, setting forth fully the facts upon which his opinion is provided in Section 12 of this Act, and shall thereafter take such steps to remedy such danger and to compel compliance with the provisions and rules of this Act, as the inspector could take in any case arising under Section 12 of this Act.

It shall be the duty of the inspector or any deputy to forward every such original complaint, so received, to the office of the Inspector of Mines, where it shall be indexed and filed among the official papers of the Inspector of Mines.

Sec. 16. ACCIDENTS.

Whenever a serious accident occurs in or about any mine, notice thereof shall be given promptly, in writing, to the inspector by the superintendent or other person having immediate charge of the work at the time of the accident. The words "serious accident" shall be construed to mean, for the purposes of this Act, accidents resulting in such injuries as, in the opinion of an accredited physician, may result in the injured person being incapacitated from work for at least fourteen days. Upon receiving such notice the inspector, or a deputy, shall, if feasible, and if the nature of the accident shows it to be necessary, proceed to the scene of the accident with all convenient speed and investigate fully the cause of the accident, and shall file the result of such investigation as a report in the office of the inspector, within twenty days thereafter. Whenever the inspector, or a deputy, cannot proceed as above to the scene of the accident, the person in charge of the mine shall be so informed by the inspector, and such person in charge must secure sworn statements of those who witnessed the accident, or if no one were present at the time of such accident, he must secure the sworn state-based, as provided in Section 14 (12) of this Act, and shall thereafter take such steps to remedy such danger and to compel compliance with the provisions and rules of this Act, as the inspector could take in any case arising under Section 14 (12) of this Act.

It shall be the duty of the inspector or any deputy to forward every such original complaint, so received, to the office of the Inspector of Mines, where it shall be indexed and filed among the official papers of the Inspector of Mines.

COMMENT:—We believe that this Section as worded would often subject both inspectors and operators to continued and unreasonable annoyance, and that the inspector should be allowed his discretion in acting on secret complaints. This belief is based on some actual known occurrences under similar laws. Therefore:

We recommend that the words "shall, in his discretion," be used instead of "must" in the fifth line.

SECTION 17 (16). ACCIDENTS.

Whenever a serious accident shall have occurred in or about any mine, notice thereof shall be given promptly in writing to the inspector by the superintendent or other person having immediate charge of the work at the time of the accident. The words "serious accident" shall be construed to include, for the purpose of this Act, accidents resulting in such injuries as, in the opinion of an accredited physician, have resulted or will result in one or more injured persons being incapacitated for work for at least four (4) days, and also all cases, occurring in or about any mine, of underground fires, breakage of ropes or other gear by which men are hoisted or lowered, overwinding while men are being hoisted, or unexpected inrush of water from old workings, whether or not personal injury or disablement results. Upon receiving such notice the inspector or a deputy shall, if feasible, and if the nature of the accident shows it to be necessary, proceed to the scene of the accident with all convenient speed, and investigate fully the cause of the accident, and shall file the result of such investigation as a report in the office of the inspector, within twenty days thereafter.

ment of those first arriving upon the scene; such statements must give, as far as possible, the details of the accident, the facts leading up to it and its probable cause; such sworn statements shall immediately thereafter be sent to the inspector, who shall file same in his office, as a public record.

Whenever, in the opinion of the inspector, the accident is of such a nature that it is likely to recur, or that it shows the existence of conditions which endanger the lives of a number of men employed in the mine, then the inspector shall, personally or by deputy, proceed to the scene of the accident. But if the inspector or his deputy cannot proceed as above to the scene of the accident, the person in charge of the mine shall be so informed by the inspector, who shall in his discretion instruct such person in charge, or any other person whom the inspector may select for the purpose, as his representative and on his behalf, to secure sworn statements of those who witnessed the accident, or if no person present at the time of the accident survives, to secure the sworn statements of those first appearing on the scene. Such sworn statements must give, as far as possible, the details of the accident, the facts leading up to it, and its probable cause. Such sworn statements shall immediately thereafter be sent to the Inspector, who shall file the same in his office as a public record.

COMMENT:—Since the "person in charge" may in some cases be suspected of blame for the accident, he should not necessarily be the one required to secure evidence, since the responsibility to investigate is on the Inspector, and he must be represented by someone satisfactory to him.

Sec. 17. LOSS OF LIFE.

Whenever loss of life occurs from accident in or about a mine, and when death results from personal injury, the superintendent or other person having immediate charge of the work at the time of the accident shall give notice to the inspector, promptly after knowledge of death comes. Whenever possible, the inspector or a deputy shall be present at every coroner's inquest held over the remains of a person killed in or about a mine. An inquest held by the coroner upon the body of a person so killed shall be adjourned by the coroner for not more than days at the request of the inspector. If the inspector or any of his deputies are not present at such inquest, the coroner in such case shall notify the inspector or his deputy intending to be present, in writing, of such adjourned inquest, and the time and place of holding the same at least five days previous thereto. Due notice of an intended inquest to be held by the coroner shall be given by the coroner to the inspector, and at such inquest the inspector and any deputy inspector shall have the right to examine and cross-examine witnesses, and such examination shall be part of the records of such inquestion. If, at any inquest held over the body or bodies of persons whose death was caused by an accident in or about the mine, the inspector or any deputy be not present, and it is found from the evidence given at the inquest that the accident was caused by neglect or by any defect in or about the mine, or because the mine was operated contrary to the provisions of this Act, the coroner shall send notice in writing to said inspector of such reported neglect or default; and the said inspector shall immediately take steps to have an investigation made of the same. The coroner before whom such an inquest is held shall promptly file with the inspector of mines a copy of the testimony taken thereat and a copy of the verdict rendered by the coroner's jury.

SECTION 18. (17). LOSS OF LIFE.

When loss of life has occurred from accident in or about a mine, the superintendent or other person having immediate charge of the work at the time of the accident shall give notice to the inspector, promptly after knowledge of death. Whenever possible, the inspector or a deputy shall be present at every coroner's inquest held over the remains of a person killed in or about a mine. Due notice of an intended inquest to be held by the coroner shall be given by the coroner to the inspector, and at such inquest the inspector or any deputy inspector shall have the right to examine and cross-examine witnesses, and such an examination shall be part of the records of such inquest. An inquest held by the coroner upon the body of a person so killed shall be adjourned by the coroner for not more than ——— days at the request of the inspector, in which case the coroner shall notify the inspector or his deputy intending to be present in writing of the adjourned inquest, and the time and place of holding the same, at least five days previous thereto. If, at any such inquest or adjourned inquest, the inspector or any deputy be not present, and it is found from the evidence given at the inquest that the accident was caused by neglect or by any defect in or about the mine, or because the mine was operated contrary to the provisions of this Act, the coroner shall send notice in writing to the inspector of such reported neglect or default; and the inspector shall immediately take steps to have an investigation made of the same. The coroner before whom such an inquest is held shall promptly file with the Inspector of Mines a copy of the testimony taken thereat and a copy of the verdict rendered by the coroner's jury.

Sec. 18. INSPECTOR TO FORWARD PAPERS TO PROSECUTING OFFICER IN CERTAIN CASES.

Whenever, in the opinion of the inspector of mines, a serious or fatal accident, in or about any mine in this State, shall have been caused by failure on the part of the operator or any employee of such mine, or by any other person or by any of them, to observe the provisions of this Act, it shall be the duty of such inspector to cause a copy of the report of such accident, or a copy of the testimony taken at the coroner's inquest together with the verdict of the coroner's jury, and all papers in his hands relating thereto, to be forwarded to the prosecuting officer of the County in which the accident or loss of life occurred, together with an accompanying statement of the inspector, showing in what particular or particulars he believes the law to have been violated and if upon the receipt thereof the Prosecuting Officer of the said County deems the facts to make a prima facie cause of action against any party, he shall present such evidence to the Grand Jury and take such further steps for the criminal prosecution of such operators, employees, or other person, as may seem advisable.

Sec. 19. STATISTICAL REPORTS OF MINE INSPECTOR.

It shall be the duty of the inspector of mines within three months after January 1st in each year, to make a report directed to the Governor and Legislature of this State, giving a statistical summary and report of the work of the inspector and deputy inspectors of mines, during the previous year ending December 31st. Such report shall contain a statement showing the number of men employed in each mine in the State, stating separately the number of men employed above ground and underground, the number and nature of fatal and serious accidents occurring in each mine, the number of inspections made, complaints filed, inquests attended, mines ordered to be vacated, violations found and any other information deemed important and relevant by the inspector of mines, together with such recom-

SECTION 19. (18). INSPECTOR TO FORWARD PAPERS TO PROSECUTING OFFICER IN CERTAIN CASES.

Whenever, in the opinion of the Inspector of Mines, a serious or fatal accident, in or about any mine in the State, shall have been caused by failure on the part of the operator, or any employee of such mine, or any other person to observe the provisions of this Act, it shall be the duty of such inspector to cause a copy of the report of such accident, or a copy of the testimony taken at the coroner's inquest together with the verdict of the coroner's jury, and all papers in his hands relating thereto, to be forwarded to the prosecuting officer of the county in which the accident or loss of life occurred, together with an accompanying statement of the inspector, showing in what particular or particulars he believes the law to have been violated, and if upon the receipt thereof the prosecuting officer of the said county deems the facts to make a prima facie cause of action against any party, he shall take such steps for the criminal prosecution of such operator, employee, or other person, as may seem advisable.

COMMENT:—Delete "present such evidence to Grand Jury" because Grand Juries are not summoned everywhere.

(19). STATISTICAL REPORTS OF MINE INSPECTOR.

This section has been changed in position only and has been placed to follow Section 8 entitled **Office and Records of Inspection of Mines** as Sec. 9.

mendations as in the judgment of the inspector of mines are necessary or desirable to the carrying out of this Act and to insure the safety of the workmen employed within the mines, subject to the provisions of this Act. Copies of such report shall be published and distributed by and at the expense of the State as a public document.

Sec. 20. REMOVAL OF INSPECTORS AND DEPUTY INSPECTORS.

Upon a petition signed by at least 100 miners, or 10 operators, or by three operators each employing 100 men underground, setting forth that the inspector, or any deputy, neglects his duties as prescribed in this Act, or that he is incompetent, and unqualified for the office of inspector, or deputy, as the case may be, under this Act, or guilty of malfeasance in office, or guilty of any unlawful act tending to the injury of miners or the operators of mines, it shall be the duty of the Court of
of the County wherein such inspector or deputy inspector resides, to issue a citation in the name of the State to the said inspector, or said deputy inspector, to appear upon not less than fifteen days' notice, on a day fixed, before said Court, and the Court shall then proceed to inquire into and investigate the allegations of the petitioners. If the Court shall find that said inspector, or deputy inspector, so petitioned against, is neglectful of his duties, as prescribed in this Act, or that he is not qualified under the provisions of this Act for such office, or that he is incompetent to perform the duties of his office, or that he is guilty of malfeasance in office, the Court so finding any or all of such facts, shall certify the facts so found to the Governor of the State, in the case of such finding against an inspector, and to the inspector of mines, in the case of such finding against a deputy inspector, and the Governor or inspector, as the case may be, shall declare the office of inspector or such deputy inspector vacant, and steps shall forthwith then be taken to appoint a properly qualified person to fill such vacant office of

REMOVAL OF INSPECTOR AND DEPUTY INSPECTORS.

(20.) COMMENT:—We recommend that this section be deleted entirely, and have incorporated in our section entitled **"Office of Inspector of Mines"** the following sentence, "The Governor may at any time remove said Inspector of Mines for incompetency, neglect of duty or malfeasance in office."

This section is unnecessarily cumbersome, and liable to many abuses.

Furthermore, under the provisions of Section 6, Article IV of the Constitution of the State of Colorado, the Governor has the right to remove any officer appointed by him, "for incompetency, neglect of duty or malfeasance in office." No doubt the Constitutions of other States contain similar provisions.

inspector or deputy inspector, as the case may be, for the remainder of the unfilled term of the removed official.

The cost of said investigation shall be borne by the removed inspector or deputy inspector, but if the allegations in the petition are not sustained, the costs shall be paid by the petitioners.

Sec. 21. CARE OF INJURED.

It shall be the duty of operators, superintendents, or any one in charge of any mine where ten or more men are employed, to keep at the mouth of the drift, shaft or slope, or at such other place about the mine as may be designated by the inspector, a stretcher and a woolen and waterproof blanket, in good condition, for use in carrying any person who may be injured at the mine. Where more than two hundred persons are employed, two stretchers and two woolen and waterproof blankets shall be kept. And at all mines a supply of antiseptic gauze, carbolated vaseline, sponges, soap, carbolic acid, tablets of bichloride of mercury, linseed oil, bandages, suitable towels and a wash basin shall be kept readily accessible for the treatment of anyone injured. *Provided,* that in all mines where five hundred or more men are employed, a First Aid Corps must be organized, consisting of the foreman or foremen, shift-bosses, time-keepers and other employees, designated by the superintendent; and it shall be the duty of the operator or superintendent of the mine to cause the organization of such; and to procure the services of a competent surgeon or physician to instruct the members of such First Aid Corps from time to time, not less than once in each calendar year, in the proper handling and treatment of injured persons before the arrival of a physician.

SECTION 20. (21). CARE OF INJURED.

It shall be the duty of the operator, superintendent or any one in charge of any mine where ten or more men are employed, to keep at the mouth of the drift, shaft or slope, or at such other place about the mine as may be designated by the Inspector, a stretcher and a woolen and waterproof blanket, in good condition, for use in carrying any person who may be injured at the mine. Where more than one hundred persons are employed, two stretchers and two woolen and waterproof blankets shall be kept. And at all mines a supply of antiseptic gauze, carbolated vaseline, sponges, soap, carbolic acid, tablets of bichloride of mercury, linseed oil, bandages, suitable towels and a wash basin shall be kept readily accessible for the treatment of any one injured. Furthermore, in all mines where one hundred or more men are employed, a First Aid Corps must be organized, consisting of the foreman or foremen, shift-bosses, time-keepers and other employees, designated by the superintendent; and it shall be the duty of the operator or superintendent of the mine to cause the organization of such; and to procure the services of a competent surgeon or physician to instruct the members of such First Aid Corps from time to time, not less than once in each calendar year, in the proper handling and treatment of injured persons before the arrival of a physician.

COMMENT:—We have changed the number of men in both cases in above section to one hundred, because we think this requirement is not unduly burdensome, and should apply to mines employing this number of men as a measure of education and discipline.

Sec. 22. MINE MAPS.

The operator of every mine, employing ten or more men underground, shall make and maintain, or cause to be made and maintained, by a competent mining engineer or surveyor, an accurate map of the working of such mine. At least once in every six months, or oftener, if necessary, the operator or superintendent of each mine shall cause to be shown accurately on the map of said mine all the excavations made therein during the time elapsed since such excavations were last shown on said map, and all parts of said mine, which were worked out or abandoned during said elapsed period of time shall be clearly indicated on said map, and all underground workings shall be surveyed and mapped before they are allowed to become inaccessible. Such maps shall, at all times, be open to the examination of the inspector of mines or any of his deputies.

SECTION 21. (22). MINE MAPS.

The operator of every mine shall cause to be made and maintained, by a competent mine surveyor, an accurate map of the workings of such mine. This map shall be drawn on a scale not smaller than fifty feet to one inch, and on it all workings shall be plotted according to the true meridian, and in such a way as to be readily understood. This map shall show, in both plan and elevation, all levels and other workings, and shall distinctly indicate every opening to the surface and every opening to other underground workings, and shall indicate whether said openings are practicable for the passage of men in emergency, or whether they are for ventilation or drainage only. It shall, further, show the places, if any, where explosives or inflammable materials are permitted to be stored underground.

On or before the completion of 1,000 lineal feet, in the aggregate, of shafts, cross-cuts, winzes and levels, or of 1,800 shifts of underground work, since the last preceding survey, the map, as above described, shall be brought up to date. All parts of the mine which have been worked out or abandoned since the time of the last preceding survey shall be indicated in a distinctive manner on said map, and all underground workings shall be surveyed and mapped before they are allowed to become inaccessible.

The map shall show upon its face, over the signature of the surveyor, the date of the latest survey. Such map or maps shall at all times be open to the inspection of the Inspector of Mines or of any of his deputies.

If any operator of any mine shall fail or refuse to comply with any of the requirements of this section within three months after receipt of written notice to so comply, from the Inspector of Mines or his deputy, the Inspector of Mines shall cause immediate cessation of all underground operations therein, excepting drainage, ventilation and such other work as shall be necessary for the preservation of the mine, and such operations shall not be resumed until the requirements of this section shall

Sec. 23. FAILURE TO MAKE MAP. REMEDY.

Whenever any operator of any mine employing more than ten men underground, shall neglect or refuse to make such map of the workings of any such mine, for a period of three months after the receipt of written notice so to do by the inspector, or by any deputy, or fails at least once in every six months to add or cause to be added to such map all excavations made within said period, then and in either of such events the inspector is hereby authorized to cause a correct survey and map of such mine to be made at the expense of the operator thereof, the cost of which shall be recoverable at law from said operator as other debts are recoverable by law. The amount advanced by the inspector for making any map as provided in this section, shall be considered as part of the expense of his office and shall be paid as such.

have been met and the Inspector of Mines shall have so certified in writing.

COMMENT:—"Ten or more men underground" is an unsatisfactory provision, for the reason that the number of men employed for any considerable period is variable, easily brought into question, and difficult of proof; and for the further reason that it makes no provision for the most extensive underground workings which may be made by less than "ten men." The provision that the survey shall be brought up "at least once in every six months or oftener if necessary" is unsatisfactory, for the reason that two or three power drills can perform an extent of work which should be surveyed much oftener than once in six months, and the provision "oftener if necessary" is too vague to be of any effect. Therefore we suggest that the lineal extent of the underground workings is the proper basis for determining when work should be mapped, because it makes no unjust distinction between hand and machine work, and is based on the thing which really determines the need of a survey, which a time limit does not.

We believe this section to be most important, and that it must be made more specific to be effective. We think that a failure to do this would result in such evasions as would in many cases destroy nearly all of the benefits desired. We regard the requirement to have a map show all openings available for escape, and to show elevations which would assist in rescue work in case of caving, as most important.

We see no reason for writing two sections on the subject of "Mine Maps," and have, therefore, combined Secs. 22 and 23.

The remedy provided in Sec. 23 of the original draft, for failure to make a map, is cumbersome and difficult to enforce. There are similar provisions in several Colorado statutes, and they are generally not enforceable for lack of funds. Moreover, even were the funds available it would, in practice, be very difficult to recover amounts so expended for surveys by the inspector. Furthermore, the remedy has the distinct disadvantage that it will make the Inspector of Mines directly responsible for the correctness of many mine maps, and thus involve him in disputes between private parties. Some operators would see in this provision a simple method of securing maps of their mines on the responsibility of a state official.

(23). FAILURE TO MAKE MAPS.

COMMENT:—We think that this section is better combined with the preceding section and therefore delete here. See Comment under Sec. 22.

Sec. 24. STORAGE OF INFLAMMABLE MATERIAL.

It shall be the duty of the operator of each mine to store, or cause to be stored, oils and other dangerously inflammable materials in a covered building, kept solely for such storage, which building shall be at least 100 feet from any other building and at least 300 feet from any powder magazine. The man in charge of such building, who shall be the superintendent, or a person expressly designated by him, shall permit only sufficient oil or other inflammable material to be taken from such building to meet the requirements of one day. If any oil or gasoline storage be so situated that leakage would permit the oil or gasoline to flow within the above specified distance, means to prevent such flow must be provided.

SECTION 22. (24). STORAGE OF INFLAMMABLE MATERIALS.

No oil or other dangerously inflammable material shall be stored in any mine; *Provided* that nothing in this section shall be construed to prevent the operator of any mine from keeping therein a quantity sufficient to meet the estimated requirements of the succeeding twenty-four hours, or prevent the operator of any mine, where daily requirement of any kind, grade or brand of such material at any level or separate mine working is less than five gallons, from making five gallons, in closed metal containers, the maximum unit of issue and distribution and the maximum quantity to be kept on hand at such level or separate mine working; *provided, however,* that the stations or places, shelves, lockers and containers for such limited supplies shall be of non-combustible material, that all greasy waste be kept in covered metal cans prior to removal from the mine, and that the situation of such stations or places and their construction, equipment and regulation shall be subject to the approval of the Inspector of Mines.

Storage of oil or other dangerously inflammable material in excess of the limited supplies provided for above shall be in a locked, covered building used solely for that purpose, at least 100 feet from any other building and at least 300 feet from any powder mazagine. If any oil or gasoline storage be so situated that leakage therefrom would flow within the above specified distances means to prevent such flow shall be provided. The superintendent shall expressly appoint a man to have charge of the storage and of issue therefrom.

Provided, however, that in cases where the situation of any mining property makes it impracticable to comply with the provisions of this section, the inspector may grant permission in writing to the operator thereof to store oil and other dangerously inflammable material at such other place on the surface, or in the mine, as will, in his judgment, offer the greatest safety to employees and the public.

It shall be the duty of the operator to enforce the carrying out of this section, and any failure on the part of said operator so to do shall be deemed a violation of this Act.

Sec. 25. STORAGE OF EXPLOSIVES.

No blasting powder or any high explosive containing nitroglycerine shall be stored in any mine. *Provided,* that nothing in this section shall be construed to prevent the operator of any mine from keeping sufficient blasting powder or other high explosive within such mine to meet the estimated requirements of such mine during the succeeding twenty-four hours; and *Provided further* that such temporary supply shall not be kept at any place within such mine, where its accidental discharge would cut off the escape of miners working therein.

All blasting powder, or other high explosive, in excess of the temporary supply required in such mine shall be stored in a magazine placed not less than three hundred feet distant from any shaft, adit, habitation, public highway, public railway, or from the boundary line of any mining property; *Provided, however,* that in cases where the location of any mining property makes it impossible to comply with the provisions of this section, the inspector may grant permission in writing to the operator of such mining property to place such magazine in some other place on such mining property, if, in the opinion of the said inspector such location shall not be dangerous to the safety of those employed within such mine.

Every magazine where powder or other high explosive is stored as provided in this section, shall be ventilated; and if it be a building above the surface of the ground it shall be provided with a lightning conductor supported on a vertical post standing clear of such magazine, and not nearer than eighteen inches from one of the walls thereof and rising at least six feet above the highest point of such magazine; such lightning conductor shall be carried to a properly laid earth plate, set in the ground at a depth below the permanent moisture line of the ground and at a distance of at least one foot outside of the foundation walls of said magazine.

It shall be the duty of the operator to enforce the carrying out of this section and any failure on the part of said operator so to do shall be deemed a violation of this Act.

SECTION 23. (25). STORAGE OF EXPLOSIVES.

No blasting powder or any high explosive shall be stored in any mine. *Provided* that nothing in this section shall be construed to prevent the operator of any mine from keeping within such mine sufficient powder or other explosive to meet the estimated requirements thereof for the succeeding twenty-four hours; and *Provided further* that such limited supply shall be kept at such a place that its accidental discharge would not cut off the escape of men within the mine.

All blasting powder or other explosive, in excess of the limited supply above specified, shall be stored in a ventilated, bullet-proof magazine placed not less than 300 feet distant from any shaft, adit, habitation, public highway, or public roadway; and it and the issue therefrom shall be in charge of a man expressly appointed for such service by the superintendent.

Provided, however, that in cases where the location of any mining property makes it impracticable to comply with the provisions of this section, the Inspector may grant permission in writing to the operator thereof to so place such magazine on surface or in such mine as, in the judgment of the inspector, will offer the greatest safety to employees and the public.

It shall be the duty of the operator to enforce the carrying out of the provisions of this section, and any failure on the part of said operator so to do shall be deemed a violation of this Act.

COMMENT:—On sections 22 and 23 (Secs. 24 and 25 of original draft).

These two sections are alike in that they deal with dangerous materials and forbid underground storage. We propose to modify the stringent provisions only through the signed permit of the Inspector.

Conditions in the snowslide regions in the high mountains of Colorado and elsewhere and the presence of mines in municipalities are alike in making underground storage in remote workings preferable to surface storage, from the standpoint of general safety. It is essential that such storage shall be away from wood or combustible material, as in a crosscut.

We know of no urgent reason why magazines should be placed at least 300 feet from the boundary of any mining property; and in many mining districts it would be impossible to find such a place without placing magazines at an unsafe and undesirable distance from the mine.

Sec. 26. MARKING OF EXPLOSIVES.

It shall be unlawful for the operator or superintendent of any mine to permit the use within such mine of any explosive containing nitro-glycerine unless there shall be plainly printed or marked, in the English language, on every original package containing such explosive the name and place of business of the manufacturer of such explosive, together with the date of its manufacture.

Sec. 27. SUPERINTENDENT TO BE APPOINTED.

The operator of every mine, within the provisions if this Act, shall appoint a man who shall be personally in charge of the mine and the carrying out of the work done therein, who shall be designated as the "Superintendent"; *Privided, however,* that nothing herein contained shall prevent the owner or operator of any mine from, personally, filling the office of "superintendent."

Provision is made (in the original Section) for lightning rods. In timbered country the trees would seem more likely to draw any lightning, and elsewhere the high gallows-frame or other mine buildings. An earth plate "below the permanent moisture line" is specified; an onerous provision in a dry country, and one which, when obeyed, merely gives an unjustified sense of security. The Dupont Company has discarded lightning rods from its requirements.

For powder, as for oils, it seems well to have a man specially appointed.

The five gallon can seems a practical minimum unit of issue for oils, etc; care in keeping these small supplies away from wood being the main consideration.

SECTION 24. (26). MARKING OF EXPLOSIVES.

It shall be unlawful for the operator or superintendent of any mine to permit the use within such mine of any high explosive, unless there shall be plainly printed or marked, in the English language, on every original package containing such explosive, the name and place of business of the manufacturer of such explosive, together with the date of its manufacture and its strength.

COMMENT:—The addition of "and its strength" conforms to the present commendable practice.

SECTION 25. (27). SUPERINTENDENT. APPOINTMENT—QUALIFICATIONS.

The operator of every mine, within the provisions of this Act, shall appoint a man who shall be personally in charge of the mine and the carrying out of the work done therein, who shall be designated as the "Superintendent."

No person shall be appointed or shall act as superintendent of any mine unless he shall be at least 25 years of age, and shall have had an aggregate of at least three years of actual experience in mines under a qualified mine superintendent, (or shall possess a certificate as such, duly issued by an examining board to be provided for under appropriate safeguards) ; *provided*, that nothing herein contained shall prevent the owner or operator of any mine, if qualified, from personally filling the office of "Superintendent."

The superintendent of every mine shall inspect, or cause an inspection to be made by some competent person or persons appointed by him, of all mining appliances, boilers, engines, magazines, shafts, shaft houses, underground workings, roofs, pillars, timbers, explosives, bell ropes, speaking tubes, telephones, tracks, ladders, dry closets and all parts and appliances of said mine in actual use, and any such person or persons appointed by the said superintendent shall at once report any defects therein to the superintendent. It shall be the duty of the superintendent upon ascertaining any such defects to take immediate steps to remedy the same so as to make the same comply with the provisions of this Act; and he shall, forthwith, notify the operator of said mine of the existence of such defects. It shall be the duty of the superintendent to appoint a competent man to have full charge, under the direction of said superintendent, of every magazine containing explosives situated on such mining property; and to make such other appointments and perform such other duties as are provided by this act to be performed by such superintendent.

COMMENT:—Changes made in this section apply to the qualifications for this office, and are made because we believe that the duties of the Superintendent require a man who can qualify under these provisions.

Provisions regarding details of mine equipment do not properly come under this law, as they are modified at every mine, and each mine must of necessity provide rules applying to its specific conditions.

We have divided original Section 27 into two sections to harmonize with Sections 28 and 29.

SECTION 26. (27). DUTIES OF SUPERINTENDENT.

The superintendent of every mine shall inspect, or cause to be inspected by some competent person or persons appointed by him, all parts and appliances of said mine in actual use, and any such person or persons appointed by the said superintendent shall at once report any defects therein to the superintendent. It shall be the duty of the superintendent upon ascertaining any such defects to take immediate steps to remedy the same so as to make them comply with the provisions of this Act. It shall be the duty of the superintendent to appoint a competent man to have full charge, under the direction of said superintendent, of every powder magazine used in connection with such mining property; and to make such other appointments and perform such other duties as are provided by this Act to be performed by such superintendent.

Sec. 28. MINE FOREMAN. APPOINTMENT.

The superintendent of every mine, within the provisions of this Act, shall appoint a man who shall be personally in charge of the carrying out of the underground workings of the mine, and who shall personally direct the work of the men employed underground therein, who shall be designated as the "Mine Foreman"; provided, however, that nothing herein contained shall be construed to prevent the superintendent of any mine from also filling the position of Mine Foreman. No person shall be appointed to the position of Mine Foreman who shall not be at least 21 years of age, and shall not have had at least two years of practical experience as an underground miner in metalliferous mines, and who shall not be able readily to read and write the English language. Any superintendent failing to make such appointment of Mine Foreman, or neglecting or failing immediately to appoint another in his place, in the event of said Mine Foreman vacating or losing his position from any cause, shall be guilty of a misdemeanor. Such appointment shall be made in writing, and it shall be the duty of such superintendent to keep posted notice of such appointment or reappointment, immediately after the same shall have been made, in at least two conspicuous places about said mine, and notices of such appointment, or any reappointment, shall be mailed immediately thereafter to the inspector of mines.

Sec. 29. DUTIES OF MINE FOREMAN.

The Mine Foreman shall attend personally to his duties in the mine, as provided in this Act, and shall see that the regulations provided herein for securing the safety of all men employed in such mine are carried out; he shall immediately report to the superintendent of the mine, or in the absence of the superintendent to the mine operator, any violations or infringe-

SECTION 27. (28). MINE FOREMAN. APPOINTMENT—QUALIFICATIONS.

The superintendent of every mine, within the provisions of this Act, shall appoint a man who shall be personally in charge of the workings of the mine, and who shall personally direct the work of the men employed underground therein, who shall be designated as the "Mine Foreman"; *provided, however,* that nothing herein contained shall be construed to prevent the superintendent of any mine from also filling the position of mine foreman. No person shall be appointed to the position of mine foreman who shall not be at least 25 years of age, and shall not have had at least two years of practical experience as an underground miner in metalliferous mines, and who shall not be able readily to read and write the English language. Any superintendent failing to make such appointment of mine foreman, or neglecting or failing immediately to appoint another in his place, in the event of said mine foreman vacating or losing his position from any cause, shall be guilty of a misdemeanor. Such appointment shall be made in writing, and it shall be the duty of such superintendent to keep posted notice of such appointment or reappointment, immediately after the same shall have been made, in at least two conspicuous places about said mine, and notices of such appointment, or any reappointment, shall be mailed immediately thereafter to the Inspector of Mines.

The mine foreman is hereby authorized to delegate part of his duties to one or more competent persons as his assistants.

COMMENT:—We think it desirable to raise the age limit.

SECTION 28. (29). DUTIES OF MINE FOREMAN.

The mine foreman shall attend personally to his duties in the mine, as provided in this Act, and shall see that the regulations provided herein for securing the safety of all men employed in such mine are carried out. He shall issue necessary warnings of unusual danger, and shall permit no person to work in an unsafe place unless for the purpose of making it safe.

ments of this Act observed by him within the mine, and shall take immediate steps to remedy the same. He shall warn all employees of danger to life or limb observed by him within the mine, and permit no person to work in an unsafe place unless for the purpose of making it safe; and shall supervise the miners in the carrying out of their work.

Sec. 30. BLASTING.

Gang bosses shall be in immediate charge, and responsible for blasting within the mine. It shall be their duty to see that no iron or steel tools shall be used for tamping, and all miners are hereby forbidden to use iron or steel tools for such purposes under penalty of a misdemeanor. It shall be the duty of the Mine Foreman to fix the time of all blasting and firing. Gang bosses and miners about to fire shots shall cause warnings to be given in every direction, and all entrances to the place or places where charges are to be fired shall be guarded while such firing is going on. Failure on the part of gang bosses or miners to comply with the provisions of this Section shall be deemed a violation of this Act. The number of shots exploding, except in cases of electric firing, shall be counted by the miner firing same. If said miner be not certain that all the shots have exploded, no one shall be permitted to enter the places where such charges were placed, for a period of thirty minutes after the fuses were lighted. Such misfire, occurring at change of any shift shall be reported to the Mine Foreman, Shift Boss and to the miner of the following shift.

The term "unsafe place" as used here and elsewhere in this Act shall mean only a place which is unsafe to an avoidable degree.

The mine foreman shall be responsible for keeping the signal system used in constant working order, and shall see to the posting of copies of the signal code at the engine room, the collar of the shaft and at all shaft stations.

It shall be the duty of the mine foreman to enforce the rules in Section 37 relating to ladders and ladderways.

COMMENT:—The addition to this section regarding assistants is taken from Rule 2, Section 37, and is simplified as to wording.

Safety, in the underground workings of a mine, is a relative term; hardly any place is absolutely safe. Moreover, work in unsafe places is sometimes necessary. All that can be done is to secure that, as far as possible, work in unsafe places be minimized, and that the men working in them realize the existence and extent of any danger, so as to guard against it.

SECTION 29. (30). BLASTING.

The mine foreman shall fix the times for all blasting, which times shall be adhered to by all employees, and no blasting shall be done at other times, excepting by the authority of the mine foreman.

Blasting may be done either by the miners working in any working place, or by men specially employed for the purpose under the direction of the mine foreman. In either case the person or persons doing such blasting shall give warnings in every direction, and shall guard every entrance to the place or places where charges are to be fired.

After blasting, no person shall enter the place where the shots were exploded, for a period of twenty minutes. In the event that the person firing same has reason to believe that one or more shots have failed to explode, he shall either return and re-charge the same, after the expiration of said period of twenty minutes, or shall leave written notice of such misfire at a designated place, or with the mine foreman or shift boss, who shall deliver the same to a miner working at the same place on the following shift.

In the event of shots fired by electricity, then it shall be unlawful for any person knowingly to enter the vicinity of the mine where such shots are fired, until the cable of the firing battery has been disconnected; it shall be the duty of the gang boss or miner in charge of the shot-firing to see that all such cables are disconnected immediately after such firing, and to examine, or direct the examination of such place where shots are fired, before any men are permitted to work therein. All miners shall immediately report to the Gang Boss, Shift Boss or Mine Foreman the finding of any loose wires under or in the rock loosened by such firing; and in such event the Mine Foreman, or in his absence the Shift Boss, or Gang Boss, shall at once order work to cease until such wires have been traced to their terminals. It shall be the duty of the Mine Foreman to see that no current of higher than 250 volts shall be used when firing by electricity.

It shall be unlawful for any miner to extract or attempt to extract explosives from a hole which has once been charged, but in every such case a fresh charge shall be inserted above the missed explosive, and the same shall be then detonated. It shall be unlawful for any miner to deepen holes, or any part of holes, left standing or abandoned, and theretofore charged with explosives.

In case of shots fired by electricity, no person shall knowingly enter the vicinity of the place where such shots were fired, until the lead wires to the firing battery or cable shall have been disconnected, and it shall be the duty of the person in charge of the shot-firing to see that such lead wires are disconnected immediately after such firing.

It shall be unlawful for any person to extract or attempt to extract the primer cartridge or cartridges from a hole which has once been charged, or to deepen holes or any part of holes left standing or abandoned and theretofore charged with explosive.

Failure on the part of any person to comply with the provisions of this section shall be a violation of this Act.

COMMENT:—We have considered it necessary to entirely redraft this section. That all blasting should be done by, or in immediate charge of, "gang-bosses," is impossible in most vein-mines. It is moreover undesirable, as tending to remove that sense of individual responsibility on the part of the miner, which is the main safeguard from accident, and the main hope for improvement in the future.

Electrical firing, on the other hand, is rarely used excepting for important headings which are subject to supervision on the part of the management; and it is practicable to make some particular person responsible for seeing that the lead-wires are disconnected.

The provision for counting shots and returning to reload should in any case apply only to places where two or more shifts are worked, for when sixteen hours or more elapse between the blasting and the return of miners, safety (which is all that here concerns us) is secured.

A majority of our Committee think this provision should preferably be eliminated entirely, for the reason that in many mines the various workings are so situated that with the long fuses, which are becoming more and more generally used, the men get so far away from the working places that it is difficult to distinguish with certainty between shots fired in different working places; and because also in many mines the direction of the air currents necessitates blasting being done successively in various working places, and sometimes men who have just blasted would, by remaining to count their holes, be exposed to the smoke and gases from other working places, and even to those from the entire mine.

Sec. 31. HOISTING ENGINEER.

It shall be the duty of every superintendent of every mine having a hoisting engine to appoint and designate one or more men, who shall be able to speak and read the English language readily, to be known as hoisting engineers. At all shafts where men are hoisted or lowered such hoisting engineers shall be not less than twenty-one years of age, and at shafts where men are not so hoisted or lowered they shall be not less than eighteen years of age. It shall be the duty of every superintendent to appoint as hoisting engineers men who are familiar with the details and working of a hoisting engine, and to permit no one, other than such duly appointed hoisting engineers, to run such engine or hoisting machinery, except that by and with the consent of the Superintendent, specified apprentices may be taught the operation of the hoisting engine at such times and under such restrictions as the Superintendent may determine to be free of risk to life and limb. Any superintendent failing to make such appointment of hoisting engineer, or knowingly appointing any hoisting engineer not qualified as above, shall be guilty of a violation of this Act.

SECTION 30. (31). HOISTING ENGINEER. APPOINTMENT.

It shall be the duty of every superintendent of every mine having a hoisting engine to appoint and designate one or more men, who shall be able to speak and read the English language readily, to be known as hoisting engineers. At all shafts where men are hoisted or lowered such hoisting engineers shall be not less than twenty-one years of age, and at shafts where men are not so hoisted or lowered they shall be not less than eighteen years of age. It shall be the duty of every superintendent to appoint as hoisting engineers men who are familiar with the details and working of a hoisting engine, and except in case of emergency to permit no one, other than such duly appointed hoisting engineers, to run such engine or hoisting machinery; except that by and with the consent of the superintendent, specified apprentices may be taught the operation of the hoisting engine at such times and under such restrictions as the superintendent may determine to be free of risk to life and limb. Any superintendent failing to make such appointment of hoisting engineers, or knowingly appointing as hoisting engineer any person not qualified as above, shall be guilty of a violation of this Act.

COMMENT:—We have inserted "except in case of emergency," the reason for which is obvious.

Sec. 32. DUTIES OF HOISTING ENGINEER.

The following rules shall be observed by every hoisting engineer employed within this State:

Rule 1. It shall be the duty of every hoisting engineer to keep a careful watch over his engine and over all machinery under his charge.

Rule 2. He shall at all times be in immediate charge of his engine, and shall not at any time delegate any of his duties to any other person, except to apprentices, duly designated as provided in this Act; provided, however, nothing herein contained shall be construed to prevent any hoisting engineer delegating to or sharing his duties with any other duly appointed hoisting engineer, or turning over the engine and machinery in his charge to any other such engineer at the end of his shift.

Rule 3. He shall familiarize himself with and use all signal codes for hoisting and lowering as directed to be used in this Act.

Rule 4. He shall not run his engine unless the same is properly provided with adequate brakes, indicators, and distance marks on hoisting ropes or cables, as provided in this Act.

Rule 5. It shall be the duty of the hoisting engineer to exclude every person from his engine room, excepting any person or persons whose duties require their presence therein, and visitors authorized by the superintendent of the mine.

Rule 6. He shall hold no conversation with anyone while his engine is in motion, or while attending to signals.

Rule 7. He must run his engine with extreme caution, whenever men are on the hoisting cage.

Rule 8. He shall not hoist men out of, or lower men into any mine or shaft at a speed greater than 800 feet per minute.

SECTION 31. (32). DUTIES OF HOISTING ENGINEER.

The following provisions shall be observed by every hoisting engineer employed within this State.

1. It shall be the duty of every hoisting engineer to keep a careful watch over his engine and over all machinery under his charge.

2. He shall at all times be in immediate charge of his engine, and shall not at any time delegate any of his duties to any other person, except to apprentices duly designated as provided in this Act; *Provided, however,* nothing herein contained shall be construed to prevent any hoisting engineer delegating or sharing his duties with any other duly appointed hoisting engineer, or turning over the engine and machinery in his charge to any other such engineer at the end of his shift.

3. He shall familiarize himself with and use all signal codes for hoisting and lowering as directed to be used in this Act.

4. He shall not run his engine unless the same is properly provided with adequate brakes, indicators, and distance marks on hoisting ropes or cables, as provided in this Act.

(5.) COMMENT:—We would delete this rule because in small mines this requirement is unnecessary, and the practice impossible to prevent.

5. He shall hold no conversation with anyone while his engine is in motion, or while attending to signals.

6. He must run his engine with special care, whenever men are being carried.

7. He shall not hoist men out of, or lower men into, any mine or shaft at a speed greater than shall have been previously sanctioned for such mine or shaft by the Inspector of Mines.

(8.) COMMENT:—It is undesirable to set any maximum hoisting speed. Eight hundred feet per minute would be extremely dangerous in many a small irregular shaft, or with some hoisting apparatus, while the same speed would be unnecessarily slow and a burdensome restriction to impose on certain well-equipped deep shafts. This is one of the matters which must be left to the discretion of the Inspector unless we should go into an enormous amount of detail relating to the speeds allowable for various shafts and types of equipment.

Rule 9. He shall inspect all hoisting machinery and safety appliances connected therewith, and all ropes and hoisting apparatus, when and as directed by the mine superintendent, and shall report to him any defects found therein.

Rule 10. After any stoppage of hoisting for repairs or for any other purpose exceeding in duration one hour, he shall run a cage or other conveyance, unloaded, up and down the working portion of the shaft, at least once, and shall not permit the cage or other conveyance to be used until the hoisting machinery and shaft are found to be in safe condition.

Rule 11. He shall do no hoisting in any compartment of a shaft while repairs are being made in the said hoisting compartment, excepting such hoisting as may be necessary to make such repairs.

Rule 12. He shall familiarize himself with and carry out the requirements of Rules 7, 8, 9, 10, 11, 12, 19 and 20 of Section 37 of this Act.

Rule 13. Any hoisting engineer or any person having in charge the hoisting machinery connected with the mine who shall wilfully violate any of the provisions of this section, or any of the rules contained therein, or who shall wilfully violate any of the provisions of rules 7, 8, 9, 10, 11, 12, 19 and 20 of Section 37 of this Act shall, upon conviction, be deemed guilty of a violation of this Act, and liable to punishment accordingly.

Rule 14. The superintendent shall post a copy of this section and the last preceding section in a conspicuous place on the door of the engine house.

(9). COMMENT:—This inspection is provided for in Section 32 (33), under **Hoisting Ropes**, and therefore should be deleted here.

8. After any stoppage of hoisting for repairs he shall run the cage or other conveyance, unloaded, up and down the working portion of the shaft, at least once, and shall not permit the cage or other conveyance to be used for carrying men until the hoisting machinery and shaft are found to be in safe condition.

(10). COMMENT:—It would be unreasonable to require running the hoisting conveyance up and down the shaft before resuming hoisting after ordinary stoppages, in the case of small hoists which are not continuously operated.

(11). COMMENT:—This is identical with Section (37), Rule (12). We would delete it from this place.

(12). COMMENT:—We would delete as unnecessary.

Any hoisting engineer or any person having in charge the hoisting machinery connected with any mine who shall wilfully violate any of the provisions of this section, or any other section of this Act, shall, upon conviction, be deemed guilty of a violation of this Act, and liable to punishment accordingly.

The superintendent shall post a copy of this section and the preceding section in a conspicuous place on the door of the engine house.

Sec. 33. HOISTING ROPES.

It shall be unlawful to use in any mine, included within the provisions of this Act, any rope or cable for hoisting or lowering either men or material, when such hoisting or lowering is done by any means other than human or animal power, unless such rope or cable shall be composed of iron or steel wires, with a factor of safety determined as hereinafter set forth, *Provided, however,* that such iron or steel wires may be laid around a hemp center.

The factor of safety of all such ropes or cables shall in no case be less than five, and shall be calculated by dividing the breaking strength of the rope as given in the manufacturer's published tables, by the sum of the maximum load to be hoisted, plus the total weight of the rope in the shaft when fully let out, plus 10 per cent. of such values, to take account of shock at starting and stopping.

It shall be unlawful to use any rope or cable for the raising or lowering of men, either when the number of breaks in any running foot or said rope exceeds ten per cent. of the total number of wires composing the rope, or when the wires on the crown of the strands are worn down to less than one-half their original diameter, or when the superficial inspection provided for in this section shows marked signs of corrosion.

All ropes must be superficially inspected once in every twenty-four hours by some competent person designated for that purpose by the superintendent, and it shall be the duty of the superintendent to cause an examination to be made once in every succeeding three months of a section of such rope or cable, then in use for hoisting and lowering men and materials in such mine. If upon any inspection such hoisting rope or cable is found to be below the requirements set forth in this section, it shall be disused for such purpose forthwith, and any operator or superintendent using or permitting the use of such hoisting rope or cable for the purpose of hoisting or lowering men thereafter, shall be guilty of an offense against this Act.

SECTION 32. (33). HOISTING ROPES AND APPURTENANCES.

Every rope or cable used for hoisting or lowering men in any mine shall be composed either of manila fibre or of iron or steel wires, *Provided, however,* that such iron or steel wires may be laid around a core or center of hemp or other suitable material.

The factor of safety of all such ropes or cables, when new, shall in no case be less than five, and shall be calculated by dividing the breaking strength of the rope as given in the manufacturers' published tables, by the sum of the maximum load to be hoisted, plus the weight of the rope when fully let out, plus ten per cent of the sum of the foregoing weights to take account of shock at starting and stopping.

It shall be unlawful to use any rope or cable for raising or lowering men, when the inspections hereinafter provided for shall have shown, either that the number of breaks in any running foot of said rope exceeds ten per cent of the total number of wires composing the rope, or that the wires on the crown of the strands are worn down to less than one-half their original diameter, or that the rope shows marked evidence of corrosion.

The working load, in pounds, for a new manila rope shall not exceed three thousand multiplied by the weight of the rope in pounds per foot.

No manila rope shall be used for more than an aggregate period of three years, and in no case beyond a period of five years after its shipment from the factory.

All ropes, together with their attachments to drum and hoisting conveyance, must be superficially inspected once in twenty-four hours by some competent person designated for that purpose by the superintendent, and it shall be the duty of the superintendent to cause an internal inspection to be made once every month of a portion of such ropes, when in use for hoisting or lowering men.

Such tests of the strength of the rope or its attachments as may, in the judgment of the Inspector of Mines, be necessary,

shall be made at such times and in such manner as the Inspector of Mines may direct.

Every rope used for carrying men shall be securely fastened to its drum, and when in use shall never be fully unwound, but at least one full turn shall remain on the drum. The method of fastening the further end of the rope shall be such that the fastening shall be capable of developing the full strength of the rope; but the use of sockets in equipment for carrying men is hereby prohibited.

Every chain, ring, bar or other piece used to connect the rope with the cage or other conveyance shall have an ultimate strength of not less than ten times the static stress to which it shall be subject under maximum load.

Every rope shall be treated with oil or some suitable rope compound at least once every month.

The use of spliced ropes for carrying men is hereby prohibited.

The installation of detaching hooks or equivalent safety appliances for protection against overwinding may be required by the Inspector of Mines in his discretion, and if so required, such installation shall be made immediately by the operator.

Changes in size of rope or cable, drum, sheave, roller, weight of load or method of attachment of rope to drum or hoisting conveyance may be required by the Inspector of Mines in his discretion, and if so required, shall be made immediately by the operator.

Every head frame must be of such a height that the hoisting conveyance may be raised without damage or interference a distance above the landing place corresponding to one full turn of the hoisting drum.

Hoisting equipment intended for unusual loads, great depths, or other conditions necessitating special designs to which the foregoing requirements do not apply may be built subject to the approval of the designs by the Inspector of Mines and not otherwise. The inspector in such cases shall be empowered to issue a written permit waiving any of the foregoing requirements which he may consider impracticable. A record

of such approval and permit shall be made and maintained in the office of the Inspector of Mines.

If any operator shall fail or refuse to comply with any of the requirements of this section within ten days after the receipt of written notice to so comply from the Inspector of Mines or his deputy, the Inspector of Mines shall cause immediate cessation of operation of the hoisting plant concerned; and such plant shall not again be operated until the requirements of the inspector shall have been met, and the Inspector of Mines so certify in writing.

COMMENT:—The most obvious difference between this section as we have written it and the original draft is in permitting the use of manila ropes. A majority of our committee believe that any appliance so extensively and successfully used and of such proven reliability as the manila rope should not be prohibited by law. There is, however, some difference of opinion on this point.

We do not, perhaps, fully understand the requirement in the original draft that a section of the rope or cable be inspected, but it seems that the cable is to be cut off, presumably close to the conveyance. In our opinion a section taken at this point cannot be considered representative, and the result of inspection thus made is therefore misleading. On the other hand the frequent opening of a rope with a marlinspike very completely supplements the daily superficial examination. Beyond this, details of tests are left to the discretion of the Inspector of Mines.

Rules 53 and 54 of Section (37), somewhat modified, have been incorporated in this section.

We recommend that the use of tapered sockets be disallowed where men are carried, not because such a socket may not be secure, if the connection is carefully made, but because the degree of security cannot be ascertained by inspection. Because of the sharp bending stresses at the place where the rope enters the socket, and the opportunity for moisture to collect there, there is always danger of sudden failure, and the rope may be materially weakened there without visible exterior evidence. We know of no case in which a thimble and clips cannot be used.

A minority of our committee are of the opinion that the use both of wire and manila cables should be specifically limited by law to a definite number of years from the date of manufacture.

A minority of our committee believe that the law should fix a minimum diameter for sheaves and drums in relation to the diameter of the rope used or, to simplify the matter, on account of different kinds of rope strands, require a minimum diameter of sheave of, say, 1,000 times the diameter of the wire composing the rope.

We have added to this section a number of details which we believe to be desirable, but have purposely left to the Inspector of Mines a wide discretionary power.

Sec. 34. CAGES FOR HOISTING MEN.

It shall be unlawful for the operator of any mine to permit the hoisting or lowering of men through a vertical shaft deeper than 300 feet, unless an iron-bonneted safety cage be used for hoisting and lowering of such men, but this provision shall not apply to shafts in process of sinking.

It shall be the duty of the operator to have all cages used in such shafts, over three hundred feet deep, and in which men are hoisted and lowered, to be constructed as follows: The bonnet shall be of two steel plates, 3-16 inch in thickness, sloping toward each side, and so arranged that they may be readily pushed upward to afford egress to persons therein, and such bonnet must cover the top of the cage in such a manner as to protect those on the cage from objects falling in the shaft. The cage shall be provided with sheet iron or steel side casing, not less than 1-8 inch thick, or with a netting composed of wire not less than 1-8 inch in diameter, and with doors made of the same material as the side casing, either hung on hinges or working in slides. These doors shall extend at least 4 feet above the bottom of the cage and must be closed when lowering or hoisting men, except timber men riding on the cage to attend to timbers that are being lowered or hoisted. Every cage must have overhead bars of such arrangement as to give every man on the cage an easy and secure hand-hold. Every cage or skip used for hoisting men must be provided with a safety catch of sufficient strength to hold the cage or skip with its maximum load at any point in the shaft in the event that the hoisting cable should break. The inspector or his deputy must see that all cages and skips are equipped in compliance with this paragraph, and that on all cages the safety catches are kept well oiled and in good working condition.

Any operator of any mine failing to comply with the provisions of this Section, within ninety days after its passage, shall be guilty of an offense against this Act.

SECTION 33. (34). HOISTING CONVEYANCES.

Every cage or skip used for carrying men in shafts shall be equipped with such safety appliances, including bonnets, side doors, overhead bars, safety catches and detaching hooks, as in the opinion of the Inspector of Mines shall be necessary and practicable. It shall be the duty of the inspector or his deputy to inspect all such equipment and to make such tests of them as he may deem necessary, and he shall make such rules as may be required for the care of these devices. Safety hooks only shall be employed when hoisting with buckets.

COMMENT:—In the opinion of this committee the detail of construction of cages and skips does not properly come under this law, but requirement for bonnets, overhead bars, side doors, safety catches and detaching hooks are safeguards that should be provided and required, if in the opinion of the inspector they are practically applicable to any particular shaft.

We have modified the wording of the provision as to safety hooks, because one form of open hook is in itself an admirable safety hook.

Sec. 35. BOILERS AND CONNECTIONS, MACHINERY, ETC., INSPECTION.

All boilers used for generating steam in and about mines shall be kept in good order, and the owner, operator or superintendent shall have them examined and inspected by a qualified person, not an employee of said operator, as often as once in six months, and oftener if the inspector or his deputy shall deem it necessary. The result of such examination, under oath of the person making such examination, shall be certified in writing to the inspector within thirty (30) days thereafter.

It shall be the duty of the operator to provide each battery of boilers with a safety valve of sufficient area for the steam to escape and with weights or springs properly adjusted; and to provide every boiler house with a steam gauge properly connected with the boilers, to indicate the steam pressure, and another steam gauge shall be attached to the steam pipe in the engine house. All steam gauges shall be placed in such position that the egineer or fireman can readily examine them and see what pressure is carried. All steam gauges shall be kept in good order, and shall be tested and adjusted as often as once in every six months and their condition reported to the inspector in the same manner as the report of boiler inspection.

All machinery used in or about the mine, such as engines, wheels, screens, shafting and belting shall be protected by covering or railing so as to prevent persons from inadvertently walking against or falling upon the same. The sides of stairs, trestles and dangerous plank walks in and around the mines shall be provided with hand and guard railing to prevent persons from falling over the sides. This section shall not forbid the temporary removal of a fence, guard rail or covering for the purpose of repairs or other operations, if proper precautions are used, and the fence, guard rail or covering is replaced immediately thereafter. It shall be the duty of the operator to carry out the foregoing provisions of this section, and failure to comply with the provisions of this section shall be deemed an offence against this Act.

(35.) COMMENT:—We believe it well to eliminate this section; the first two paragraphs taking us far afield, and the last one being better cared for by others that are similar.

Our special field is that which is inherent and distinctive in our industry. To go beyond is to dissipate our energies, puzzle the very men who need help, cloud the statute-books with conflicting laws and, finally, rouse the enmity of the boiler inspection forces, which are usually provided by states and municipalities.

Sec. 36. PROHIBITED EMPLOYMENT OF WOMEN AND CHILDREN IN MINES.

No woman or girl, and no boy under the age of sixteen years, shall be employed or permitted to work within any mine within this State, included in the provisions of this Act, and it shall be unlawful for any operator to employ such persons within such mine. Before any boy shall be permitted to work in any mine he must produce to the operator, superintendent or mine foreman thereof, an affidavit made by the parent, guardian or next of kin of said boy, duly verified, containing a statement that he, the said boy, is at least sixteen years of age.

Any person who violates and does not comply with the provisions of this Section is guilty of an offence against this Act.

Provided, however, that nothing in this Section contained shall be construed to prevent the employment of women, or children under sixteen years, in clerical or office positions in the offices or buildings connected with such mine.

SECTION 34. (36). PROHIBITED EMPLOYMENT OF WOMEN AND CHILDREN IN MINES.

No female, and no boy under the age of sixteen years shall be employed or permitted to work underground within any mine in this State, included in the provisions of this Act; and it shall be unlawful for any operator to employ such persons within such mine. Before any boy shall be permitted to work underground in any mine he must deliver to the operator, superintendent or mine foreman thereof, an affidavit made by the parent, guardian or next of kin of said boy, duly verified, containing a statement that he, the said boy, is at least sixteen years of age. *Provided, however,* that nothing in this section contained shall be construed to prevent the employment of women, or children under sixteen years of age, in work at the surface of such mine.

(36.) COMMENT:—It will be generally conceded that underground labor of women and children should be absolutely prohibited by any code which it is proposed to enact uniformly throughout the country, although there is no reason to suppose that such a prohibition will ever be necessary in the Western States.

We believe however that it is desirable that the law should specifically approve the employment of boys in the lighter forms of surface work, subject to such factory legislation as is or will be operative in most States.

To those who have lived in the older and more settled Western mining towns, no problem is more serious or more disquieting than that which results from the unemployment of boys between school age and that at which they are fitted to compete with men. The physical and moral effects of idleness at this age are deplorable, as is also the resulting unfitness when employment commences at full wages, at from eighteen to twenty years of age.

Work in such occupations as ore-sorting would give the necessary training of hand and eye, in addition to helping out family earnings, and avoiding the dangers of a period often devoted to the acquisition of ineradicable bad habits, such as loafing and worse.

Sec. 37. RULES.

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(37) RULES.

GENERAL COMMENT:—This committee fails to understand the object of placing certain matters in the form of "Rules" rather than in "Sections." It seems to us unusual, if not positively objectionable in a legislative act to repeat the same provision in different sections in slightly different language as is here done. For example, compare Rules 2, 3 and 4 with Section 29, Rules 53, 54 and 55 with Section 33, and Rules 66, 68 and 69 with Section 47. Why should not the matter in these rules, which relates to the same subject, be placed together, either in the rules or in the section? If the object of this list of "Rules" is to put certain matters in a more emphatic form so that they will be more frequently read by the common miner, why include such matter as covered by Rules 23 and 24, which are not to guide the workman, but affect the operator only?

For the sake of following the original draft, and because the final arrangement of the whole matter falls on the original committee, we forbear subdividing this entire section into smaller sections instead of "Rules," but have consolidated some of the duplicated paragraphs and thus reduced the number of rules from 73 to 50.

Further, if "rules" are things to guide persons in their actions, rather than specifications for construction work, other matter, for example the subject of "**Ladders and Ladderways,**" had better be removed from this section and placed in a distinct section.

A minority of the committee believe that Rules 8 to 13, inclusive, and Rules 26 and 27 should be deleted. They are too detailed and, for the most part, too trivial to be enacted into a general statute. They are of the elementary text-book order, and make a great show of prohibiting things which no man who has ever been underground would do except in malice. In that case he would not be restrained by any number of rules, and the present criminal statutes provide punishment for such things.

If we are to enact into statutory form every detail of good mining practice, the draft submitted is a bare beginning. If we are not to go into this detail in all things, we certainly should not do so in a few instances selected at random.

SECTION 37—(Continued).

The following general rules shall be observed in and about every mine within this State to which this Act applies.

ADDITIONAL DUTIES OF MINE FOREMAN AND ASSISTANT MINE FOREMEN.

Rule 1. The operator and superintendent of every mine shall use every precaution to insure the safety of the workmen in the mine in all cases, whether provided for in this Act or not, and shall place the underground workings thereof and all that is related to the same under the charge and daily supervision of a competent person who shall be called "Mine Foreman."

Rule 2. Whenever a mine foreman cannot personally carry out the provisions of this Act, so far as they pertain to him, the superintendent shall authorize him to employ a sufficient number of competent persons to act as his assistants, who shall be subject to his orders, and shall be known as "Assistant Mine Foremen," and they shall be under the direct supervision of the mine foreman and shall carry on the duties of the mine foreman as directed by him, and as prescribed in Section 29 of this Act.

Rule 3. The mine foreman shall have charge of carrying out or directing the carrying out of his duties as prescribed in Section 29 of this Act; and any superintendent who shall direct or cause a mine foreman to disregard the provisions of this Act shall be amenable in the same manner as the mine foreman.

Rule 4. The mine foreman shall see that all dangerous places are properly fenced off and proper danger signal boards are so hung on such fencings that they may be plainly seen.

SECTION 35. (37)—(Continued).

ADDITIONAL DUTIES OF MINE FOREMAN AND ASSISTANTS.

COMMENT:—Rule 1, although placed under the heading **Additional Duties of Mine Foreman and Assistant Mine Foreman,** is a direction to the operator and superintendent, and is in fact a statement of the purpose of the entire Act. The appointment of mine foreman is already provided in Section 27 (28). We would delete the rule.

COMMENT ON RULES (2), (3) AND (4):—These three rules are covered under Section 28 (29), entitled **Duties of Mine Foreman,** and we would therefore recommend deleting them from this place.

SECTION 37—(Continued).

CANDLES.

Rule 5. No candle shall be left burning in a mine or any part of a mine when the person using the candle departs from his work for the day.

FIRE FIGHTING HELMETS.

Rule 6. The operator or superintendent of a mine employing more than 50 men underground shall provide, and keep in a readily accessible place, at least two fire fighting helmets to be used in case of emergency.

CAGES.

Rule 7. At all mines where hoisting is done by cage or skips from two or more levels, a man shall be employed whose duties shall be to load and unload the cage or skip and to give all signals to the hoisting engineer. The superintendent is responsible for the enforcement of this rule.

Rule 8. Any person riding upon any cage, skip or bucket that is loaded with tools, timber, powder or other material, except for the purpose of assisting in passing such material through a shaft or incline, and then only after a special signal has been given, shall be guilty of a violation of this Act.

Rule 9. When tools, timber or other materials are to be lowered or hoisted in a shaft, their ends, if projecting above the top of the bucket, skip or other vehicle, shall be securely fastened to the hoisting rope or to the upper part of the vehicle, and all tools, timber or other materials loaded upon a cage must be securely lashed before being lowered or hoisted.

SECTION 35. (37)—(Continued).

COMMENT ON RULES (5) AND (6):—These Rules, together with provisions for fire extinguishers or other fire fighting apparatus, should be combined into a section under a caption, **Fire Protection.** This subject is as important as any mentioned in the Act, and we have placed it as Section 40.

COMMENT ON RULE (7):—In the opinion of this committee this rule would be unduly burdensome and impracticable in small mines, and is the regular practice in all large mines, therefore we would delete it.

Rule 1. (8.) Any person riding upon any cage, skip or bucket that is loaded with tools, timber, powder or other material, except for the purpose of assisting in passing such material through a shaft or incline, and then only after a special signal has been given, shall be guilty of a violation of this Act.

Rule 2. (9.). When tools, timber or other materials are to be lowered or hoisted in a shaft, their ends, if projecting above the top of the bucket, skip or other vehicle, shall be securely fastened to the hoisting rope or to the upper part of the vehicle, and all tools, timber or other materials loaded upon a cage must be securely lashed before being lowered or hoisted.

SECTION 37—(Continued).

HOISTING WHILE SHAFT-SINKING.

Rule 10. In no case shall a cage, skip or bucket or other vehicle be lowered directly to the bottom of the shaft when men are working there, but such cage, skip or bucket or other vehicle must be stopped at least fifteen feet above the bottom of such shaft until the signal to lower further has been given to the hoisting engineer by one of the men at the bottom of the shaft, *provided,* however, that this rule shall not apply to shafts of less than fifty feet in depth.

DEEPENING SHAFT—PROTECTION.

Rule 11. Persons engaged in deepening a shaft in which hoisting from an upper level is going on shall be protected from the danger of falling material by a suitable covering extending over the whole area of the shaft, sufficient openings being left in the covering for the passage of men, a bucket or other conveyance used in the sinking operations. It shall be the duty of the superintendent of the mine to enforce this rule, and failure so to do shall be deemed a violation of this Act.

Rule 12. No hoisting shall be done in any compartment of a shaft while repairs are being made in that compartment, excepting such hoisting as is necessary in order to make such repairs.

Rule 13. Whims in use at or in mines shall be provided with a suitable stopper, or some other reliable device, to prevent running back of the bucket or other conveyance.

HOOKS.

Rule 14. No open hook shall be used with a bucket in hoisting. Safety hooks only shall be employed.

CROSSHEADS.

Rule 15. All shafts more than three hundred feet deep from which hoisting is done by means of a bucket must be provided

SECTION 35. (37)—(Continued).

HOISTING WHILE SHAFT-SINKING.

Rule 3. (10.) In no case shall a cage, skip, bucket or other vehicle be lowered directly to the bottom of the shaft when men are working there, but such cage, skip, bucket or other vehicle must be stopped at least fifteen feet above the bottom of such shaft until the signal to lower further has been given to the hoisting engineer by one of the men at the bottom of the shaft, *provided, however*, that this rule shall not apply to shafts of less than fifty feet in depth.

DEEPENING SHAFT—PROTECTION.

Rule 4. (11.) Persons engaged in deepening a shaft or repairing the lower part of a shaft in which hoisting from an upper level is going on shall be protected from the danger of falling material by a suitable covering extending over the whole area of the shaft, sufficient openings being left in the covering for the passage of men, a bucket or other conveyance used in the sinking operations. It shall be the duty of the superintendent of the mine to enforce this rule, and a failure so to do shall be deemed a violation of this Act.

Rule 5. (12.) Except as provided in Rule 4 (11) no hoisting shall be done in any compartment of a shaft while repairs are being made in that compartment, excepting such hoisting as is necessary in order to make such repairs.

Rule 6. (13.) Whims shall be provided with reliable devices to prevent running back of the bucket or other conveyance.

(14.) COMMENT:—Has been incorporated into Section 33, entitled, **Hoisting Conveyances.** (Old Sec. No. 34.)

(15). Delete for following reasons: The subject of crossheads is one on which there is the widest variation of opinion among operators, some

SECTION 37—(Continued).

with suitable guides, and in connection with the bucket there must be a crosshead traveling upon these guides. The height of the crosshead shall be at least two-thirds of its width. If the crosshead be a type that is not secured to the hoisting rope, a stopper must be securely and rigidly fastened to the hoisting rope at least seven feet above the rim of the bucket.

SIGNALS.

Rule 16. Every shaft, if exceeding fifty feet in depth, shall be provided with an efficient means of interchanging distinct and definite signals between the top of the shaft and the lowest level and the various intermediate levels from which hoisting is being done. The signalling apparatus shall be a cord or wire actuating a knocker, bell or whistle, which may be supplemented by a speaking tube, or telephone, or an electrical system.

Rule 17. Special care must be taken to keep the signalling apparatus in good order.

PUNISHMENT FOR INTERFERENCE WITH SIGNALS.

Rule 18. Any person who shall interfere with or impede any signalling in the mine within this State, or who shall knowingly damage any such signal system, or who shall knowingly give or cause to be given any wrong signal within the mine, or who shall ride upon any cage, skip or bucket at a time when signals have been given informing the hoisting engineer that no person is so riding, shall be guilty of a violation of this Act, and shall be punished accordingly.

SIGNAL CODES.

Rule 19. The following signals shall be used: One bell, hoist (when engine is at rest); one bell, stop (when engine is in motion); two bells, lower; three bells, men on cage about to ascend or descend; four bells, blasting signal. Upon receiving the blasting signal of four bells, the engineer must answer by raising the bucket a few feet and letting it back slowly, and then upon receiving the signal of one bell, he shall hoist the men away from the blast.

SECTION 35. (37)—(Continued).

maintaining that their use is required for good practice, while others refuse to use them under the same conditions, and hold that they cause as many accidents as they prevent. It is probable that their chief benefit is in the prevention of spinning, and this may be obviated by the use of "non-spinning rope,' which is now a standard commercial article; therefore we think it best to eliminate this rule from a general mine accident law.

SIGNALS AND SIGNAL CODES.

Rule 7. (16.) Every shaft, if exceeding fifty feet in depth, shall be provided with a positive means of transmitting distinct and definite signals from every level to the hoisting engineer.

Rule 8. (17.) It shall be the duty of the mine foreman to see that the signalling apparatus is kept in working order.

Rule 9. (18.) Any person who shall interfere with or impede any signalling in any mine within this State, or who shall knowingly damage any signal system, or who shall knowingly give or cause to be given any wrong signal within the mine, or who shall ride upon any cage, skip or bucket at a time when signals have been given informing the hoisting engineer that no person is so riding, shall be guilty of a violation of this Act.

Rule 10. (19.) The following signals shall be used: One bell, hoist (when engine is at rest); one bell, stop (when engine is in motion); two bells, lower; three bells, men on the cage; four bells, blasting signal. Upon receiving the blasting signal of four bells, the engineer must answer by raising the bucket a few feet and letting it back slowly, and then upon receiving the signal of one bell, he shall hoist.

SECTION 37—(Continued).

Rule 20. Special signals in addition to the above may be used in any mine, provided they are easily distinguished by their sound or otherwise from the foregoing code, and do not interfere with it in any way.

Rule 21. An easily legible copy of the above code, and of any special code adopted in any mine, shall be printed on a board or metal plate not less than eighteen inches by eighteen inches, and shall be securely posted in the engine room, at the collar of the shaft, and at each level or station. The superintendent of the mine shall be held responsible for the carrying out of this rule.

TIMBERING.

Rule 22. The timbers in all manways in daily use shall be cleared of all loose rock lodged upon them at least once in every twenty-four hours. Manways in daily use shall be kept clear of obstructions.

FENCING DISUSED SHAFTS.

Rule 23. The mouth of every shaft or entry to a mine which, for the time being is out of use, or is used only as an airway, and the approach to every open working other than ordinary prospecting trenches, and all elevated and exposed platforms and gangways, shall be kept securely fenced or otherwise protected.

ABANDONED SHAFTS.

Rule 24. All abandoned shafts or other abandoned excavations shall be securely covered or fenced; *provided, however*, that in the case of abandoned open cuts fencing only shall be required.

SECTION 35. (37)—(Continued).

Rule 11. (20.) Special signals in addition to the above may be used in any mine, provided they are easily distinguishable by their sound or otherwise from the foregoing code, and do not conflict with it in any way.

Rule 12. (21.) An easily legible copy of the above code, together with any special code in use in any mine, shall be printed on a board, cloth or metal plate with letters and figures not less than half an inch in height, and shall be securely posted in the engine room, at the collar of the shaft, and at each level or station.

(22.) COMMENT:—First, if used here at all, the caption should be "**Manways**" and not "**Timbering.**" This rule, as written, is so exacting as to rouse strong opposition from practical operators; and for this reason we recommend a milder form and have incorporated it in Rule 25.

A minority of the committee consider the matter of sufficient importance to occupy a Rule, but only in the following more elastic form:

MANWAYS.

Rule—. All manways in daily use shall be kept clear of obstructions, and of any loose rock or other debris which is liable to dislodgement.

(23 and 24.) COMMENT:—For the purpose of this law we fail to see a reason for providing separate rules for "**Disused Shafts**" and for "**Abandoned Shafts.**" We would combine Rules (23) and (24) into one rule, headed "**Protection at Disused Openings,**" as follows:

PROTECTION AT DISUSED OPENINGS.

Rule 13. (23 and 24.) The mouth of every shaft or incline entry to a mine, which opening is abandoned or for the time being is out of use, or is used only as an air-way or as a manway, and the approach to every open working more than ten feet deep, shall be kept securely covered or fenced or otherwise protected.

NOTE:—The phrase "And all elevated and exposed platforms and gangways" has been eliminated, the subject being covered by Rule 19, under "**Machinery Protection.**"

SECTION 37—(Continued).

PENALTY FOR DESTROYING FENCES AND COVERINGS.

Rule 25. Any person who shall wilfully remove, injure or destroy all or any part of any coverings or fences provided for in Rules 23 and 24 of this Section shall be guilty of a violation of this Act and shall be punished accordingly.

LIGHTING.

Rule 26. Stationary lights shall be provided during the working hours at all stations at vertical and inclined shafts during the time the same are in actual use; and also at all stations on the levels where hoisting or hauling is effected by means of machinery; and also at night at all working places on the surface, and at the head of any shafts not fenced or covered.

Rule 27. All places where hoisting, pumping or other machinery is erected, and in the proximity of which persons employed in the mines are working or moving about, shall be so lighted that the moving parts of such machinery can be clearly distinguished.

MANHOLES.

Rule 28. In every mine in which mechanical haulage is employed there shall be at intervals of not more than one hundred yards, on each main haulage way, places of refuge, affording a space of at least two and one-half feet in width between the widest portion of the car or train running on the tramway and the side of the gallery.

Rule 29. Every manhole and place of refuge shall be kept constantly clear, and no refuse shall be placed therein, and no person shall in any way prevent access thereto.

SECTION 35. (37)—(Continued).

Rule 14. (25.) Any person who shall wilfully remove, injure or destroy any part of any covering, fence or railing provided for in this Act shall be guilty of a violation of this Act.

LIGHTING.

Rule 15. (26.) Stationary lights shall be maintained during working hours at all stations at shafts during the time such stations are in actual use.

Rule 16. (27.) All places where hoisting, pumping or other machinery is operated, and in the proximity of which persons employed in the mines are working or moving about, shall be so lighted that the moving parts of such machinery can be clearly distinguished.

PLACES OF REFUGE.

Rule 17. (28.) In every mine working (excepting shafts) where mechanical haulage is employed there shall be at intervals of not more than three hundred feet places of refuge, affording a clear space of a least two and one-half feet in width outside of the widest portion of the car or train.

Rule 18. (29.) Every such place of refuge shall be kept constantly clear.

SECTION 37—(Continued).

MACHINERY AND PROTECTION.

Rule 30. All exposed machinery which when in motion would be dangerous to persons coming in contact therewith shall be securely guarded by a fence or railing. All electrical conductors shall be placed so as to protect any persons, so far as is possible from coming into contact with the same.

Rule 31. No electrical current higher than two hundred and fifty volts shall be carried by any naked wire in any mine.

PROTECTION AGAINST WATER.

Rule 32. No raise shall be allowed to approach within ten feet of any portion of a winze, stope or other opening in which there is a dangerous accumulation of water, unless such winze or stope be first unwatered by bailing or pumping or by means of a bore from the raise.

Rule 33. When advancing a drift, adit level or incline toward a mine working that is suspected to be filled with water, a bore hole must be kept at least 20 feet in advance of the breast of the drive; and also if necessary in directions laterally from the course of the drive. Such a working place must not exceed six feet in width and such additional precautionary measures shall be taken as may be deemed necessary to obviate the danger of a sudden breaking through of water.

SECTION 35. (37)—(Continued).

MACHINERY PROTECTION.

Rule 19. (30.) The operator of every mine in this State shall provide protection for all machinery in or about such mine, which protection shall be satisfactory to the Inspector of Mines.

COMMENT:—The committee suggests that the subject of **Electrical Protection** have a separate heading, and that a portion of Rules (30) and (31) be placed under this head.

ELECTRICAL PROTECTION.

Rule 20. (30.) All electrical conductors shall be placed so as to protect any persons, so far as is possible, from coming into contact with them.

Rule 21. (31.) No electrical current shall be carried by any naked wire in any mine, except in case of properly guarded trolley wires, or signal systems requiring bare wires.

COMMENT:—A minority of the committee would prefer the rule written thus:

Rule 31. No electric current of higher potential than one hundred and twenty-five volts shall be carried by any naked wire in a mine, except in the case of properly guarded trolley wires, or that of signalling systems requiring bare wires.

PROTECTION AGAINST WATER AND GAS.

COMMENT:—In the opinion of this committee the varying physical conditions make it impracticable to frame any rational detailed rules for this subject, therefore we recommend the following substitute for Rules 32, 33 and 34:

Rule 22. (32, 33, 34.) Whenever the workings of a mine shall be in the immediate vicinity of, and approaching old workings of the same or another mine known or suspected to contain a dangerous accumulation of water or gas, it shall be the duty of the superintendent to notify the Inspector of Mines, giving the latter all the information which the superintendent shall have been able to obtain with reference to such old workings, and to submit to the inspector for his approval details of the precautions for safety which it is proposed to adopt. Should

SECTION 37—(Continued).

Rule 34. In every mine, where in the opinion of the inspector of mines, there is danger of a sudden inburst of water, such additional raise, drifts, or other workings shall be constructed as are necessary in the opinion of the inspector to ensure the escape of workmen from the lower workings.

Ladders and Ladderways.

Rule 35. The space between the rungs of a ladder shall not exceed 12 inches.

Rule 36. The rungs of a ladder shall in no case be less than 3 inches from the wall of the shaft, or any opening in which it is used.

Rule 37. Every ladderway constructed and fixed in a vertical shaft more than 100 feet deep which may be used for the ascent and descent of persons working in the mine shall have substantial platforms at intervals of not more than 20 feet and the inclination of any ladder or section of a ladder shall not exceed 80 degrees from the horizontal.

SECTION 35. (37)—(Continued).

the inspector consider the proposed precautions insufficient, he shall prescribe such further precautions as shall, in his judgment, be necessary, all of which precautions shall be observed by the superintendent.

LADDERS AND LADDERWAYS.

Rule 23. (35.) The space from center to center between the rungs of every ladder shall be twelve inches.

COMMENT:—We recommend that the rungs in every ladder should be uniformly spaced, because in our opinion the greatest danger of falling when climbing ladders is when one's foot suddenly fails to find the rung at the expected spot. Irregularly spaced rungs are nearly as dangerous as missing rungs.

Miners are everywhere accustomed to rungs 12 inches apart, and we see no reason why this uniform distance should not be specified by law.

Rule 24. (36.) The centers of the rungs of a ladder shall in no case be less than three inches from the wall of the shaft or other opening in which it is used.

Rule 25. (37). Every ladderway, having an inclination of more than forty-five degrees, in use as a main thoroughfare, excepting in shafts in which the hoisting is done exclusively by human power, shall have substantial platforms at intervals of not more than twenty feet in vertical distance; and the inclination of any ladder, or any section of a ladder, shall not exceed eighty-five degrees from the horizontal. Every such ladderway shall be kept clear of obstructions and of any loose rock or other debris which is liable to dislodgement. *Provided* that this rule shall not apply to raises in process of construction, or to passageways in stopes and chutes.

(37.) COMMENT:—This rule should not be limited to "vertical" shafts. Steep inclines, whether shafts or raises, need such protection nearly as much as vertical shafts. The insertion of the phrase "in vertical distance" is intended to equalize the safety requirements for vertical shafts and inclines.

SECTION 37—(Continued).

Rule 38. All platforms except for an opening large enough to permit the passage of a man shall be closely covered.

Rule 39. Ladders shall project at least three feet above every platform in the ladderway and at least three feet above the collar of the shaft, unless hand rails are fixed at such places.

Rule 40. In ladderways not exceeding 100 feet in depth, ladders may be fixed vertically; over this depth no vertical ladders shall be used.

Rule 41. Under no circumstances shall any ladder inclining backward from the vertical be installed.

Rule 42. Ladderways shall be provided in all shafts in the course of sinking to within such a distance from the bottom thereof as will secure them from damage by blasting, but from the end of which ladderways chain or wooden extension ladders shall be extended to the bottom of the shaft.

ENFORCEMENT OF RULES 35 TO 42.

Rule 43. It shall be the duty of the Superintendent to enforce the carrying out of Rules 35 to 42, and his failure so to do shall constitute a violation of this Act.

PASSAGEWAY AROUND SHAFT.

Rule 44. All stations or levels shall have a passageway around or through the working shaft so that crossing over the hoisting compartment may be avoided.

SUMPS.

Rule 45. All sumps shall be securely planked over.

SECTION 35. (37)—(Continued).

As to the inclination of ladders, we should of course prefer ladders inclined at seventy-five degrees from the horizontal; but in narrow vertical ladderways it is not possible to give the ladders the ideal inclination, without spacing platforms impracticably close. The platforms constitute the main requirement for safety; the inclination of the ladders (excepting as to prohibition of ladders which incline backwards) being a requirement rather for ease in climbing than for actual safety. We therefore recommend that ladders as steep as 85 degrees be permitted, believing that where possible a less degree of inclination will be employed.

Rule 26. (38.) Every such platform, except for an opening large enough to permit the passage of a man, shall be closely covered.

Rule 27. (39.) Ladders shall project at least three feet above every platform in the ladderway, and at least three feet above the collar of the shaft, unless other handholds are fixed at such places.

(40.) Delete because of change of Section 39. (40.)

Rule 28. (41.) Under no circumstances shall any ladder inclining backwards from the vertical be installed.

Rule 29. (42.) Fixed ladders shall be provided in all shafts in the course of sinking to within such a distance from the bottom as will secure them from damage from blasting; from the end of which ladders chain, wire rope or portable wooden ladders shall be extended to the bottom of the shaft.

Rule 30. (New). It shall be unlawful to throw or drop tools or timbers down any manway or ladderway.

(43.) COMMENT:—Delete because we have placed this duty under section entitled **Duties of Mine Foreman.**

(44.) See Rule 36.

SUMPS.

Rule 31. (45.) All sumps shall be securely planked over or fenced around.

SECTION 37—(Continued).

STOPES.

Rule 46. In stopes timbered with square sets, the working floors shall be closely and securely lagged over. Lagging shall be long enough to reach clear across the caps.

WINZES OR RAISES.

Rule 47. Winzes or raises shall not be started in the direct line of a drift, but shall be offset from the drift.

Rule 48. The opening of such offset winze shall be protected by a fence or guard rail not less than three feet or more than four feet in height above the level of the drift.

Rule 49. Existing winzes opening directly from the floor of a drift or stope must be kept covered by a substantial hatch, or planking, except when in use, at which time passage to persons other than those working at the winze shall be barred off by a substantial rail across the roads of access to the openings.

SHAFT STATIONS.

Rule 50. At all shaft stations a gate or a guard rail not less than three feet or more than four feet above the floor must be provided and kept in place across the shaft, except when cage, skip or bucket is being loaded, but this prohibition shall not forbid the temporary removal of the gate or rail for the purpose of repairs or other operations, if proper precaution to prevent danger to persons be taken.

SECTION 35. (37)—(Continued).

(46.) COMMENT:—Delete because this is a provision for convenience in operating stopes rather than for safety of employees.

WINZES AND RAISES.

Rule 32. (47.) Every winze shall be kept covered by a substantial hatch or planking, or shall be guarded by a fence, or a guard rail not less than three nor more than four feet above the floor of the drift.

Rule 33. (48.) The bottom of every raise shall be so guarded that there shall be a safe passage-way past it through the drift.

Rule 34. (49.) Winzes opening directly from the floor of a drift or stope must be kept covered by a substantial hatch or planking, except when in use, at which time passage to persons other than those working at the winze shall be barred off by a substantial rail across the roads of access to the openings.

COMMENT:—Rules (47-49.) There are many cases of narrow veins with bad walls where the expense and danger resulting from unnecessarily breaking into the walls may outweigh any additional safety secured by insisting that all winzes and raises be offset from the drifts. We have therefore provided that winzes and raises wherever located shall be so guarded as to provide the requisite safety.

SHAFT STATIONS.

Rule 35. (50.) At every shaft station a gate or guard rail not less than three nor more than four feet above the floor, must be provided and kept in place across any open side of the shaft at such station, except when cage, skip or bucket is being loaded or unloaded there.

PASSAGEWAY AROUND SHAFT.

Rule 36. (44.) Every shaft station or level shall be provided with a passageway around the hoisting compartments.

SECTION 37—(Continued).

TOP OF SHAFT.

Rule 51. The top of all shafts shall be protected by a gate, so that persons or foreign objects cannot fall into the shaft.

Rule 52. If hoisting be done from greater depth than 100 feet, by means of a bucket, shaft doors must be constructed that will prevent any material from falling into the shaft while the bucket is being dumped.

HOISTING ROPES.

Rule 53. Every rope used for hoisting or lowering men or materials shall be securely fastened to its drum and when in use shall never be fully unwound, but at least one full turn shall remain on the drum.

Rule 54. The further end of the rope shall either be securely fastened within a tapered socket, or else it shall be bound around an oval thimble and then fastened to itself by not less than twelve clamps or bolts.

Rule 55. Every rope shall be treated with oil or some suitable rope compound at least once every month. Such compound must be chemically neutral, and must be of such consistency as to penetrate the strand and not merely cover the surface of the rope.

EXPLOSIVES AND FUSES.

Rule 56. Every mine thawing in excess of a daily average of 100 pounds of dynamite shall be provided with a separate building for that purpose.

Rule 57. Dynamite shall not be thawed by any means other than a steam bath or a hot water device and such thawing device shall not be allowed to become hotter than can be borne by the naked hand.

Rule 58. It shall be unlawful to thaw dynamite by placing it near a fire or steam boiler.

SECTION 35. (37)—(Continued).

TOP OF SHAFT.

Rule 37. (51.) The top of every shaft equipped with a cage or skip shall be provided with a door or gate which shall be kept closed, except when the cage or skip is being loaded or unloaded there.

Rule 38. (52.) If hoisting be done with a bucket by other than human power, tightly closing doors shall be used at the top of the shaft.

COMMENT:—Rules (51) and (52), as originally drafted, would not exempt a shaft equipped with a windlass.

HOISTING ROPES.

COMMENT:—Rules (53), (54) and (55) have been incorporated, as far as seemed desirable, into Sec. 32 (33), and should be deleted here.

EXPLOSIVES AND FUSES.

Rule 39. (56.) Every mine thawing in excess of a daily average of one hundred pounds of explosives shall be provided with a special place for that purpose.

Rule 40. (57.) Devices for thawing explosives shall be so constructed that the temperature of the thawing chamber cannot exceed that which can be borne by the naked hand.

COMMENT:—The purpose of the change of this rule is to admit of the use of a suitable electrical device.

Rule 41. (58.) No explosive shall be thawed by placing it near a fire or steam boiler.

SECTION 37—(Continued).

Rule 59. It shall be unlawful to thaw dynamite in a steam bath by using live steam.

Rule 60. It shall be unlawful for any person knowingly to distribute frozen dynamite to any person working in any mine.

Rule 61. No explosive shall be taken into any mine except in a securely covered case.

Rule 62. Detonators shall not be transported in the same vehicle or carried in the same case with dynamite or other explosive.

Rule 63. No fuse shall be used in any mine that burns faster than one yard in eighty seconds or slower than one yard in one hundred seconds.

Rule 64. It shall be unlawful for any person to use within any mine any fuse unless the rate of burning be stamped by the manufacturer on the package containing such fuse.

Rule 65. Notice shall be posted at the entrance of every mine stating the rate of burning of the fuse used in such mine. The Superintendent shall be responsible for the carrying out of this rule.

SECTION 35. (37)—(Continued).

Rule 42. (59.) No explosive shall be thawed by direct contact with steam.

Rule 43. (60.) No person shall knowingly load any hole with frozen explosives.

COMMENT:—In some mines the winter temperatures are so low that dynamite will freeze solid in a short time, and it is practically impossible to avoid the use of individual thawing appliances at each working-place. In such cases explosives may necessarily have to be distributed in a frozen condition.

This committee expresses a confident hope that the use of low-freezing explosives will, in the near future, obviate all difficulties in connection with thawing.

(61.) Delete. Impracticable.

(62.) COMMENT:—In the opinion of this committee the following better expresses the intent of this rule.

Rule 44. (62.) Detonators shall not be carried in the same receptacle with other explosives, nor transported unattended in any vehicle which contains other explosives, but this rule shall not apply to primer cartridges of explosive in which detonators have been previously inserted.

Rule 45. (New) It shall be unlawful for any person to leave unused explosives or detonators in any drift, stope or other mine working.

Rule 46. (63.) No fuse that burns faster than three feet in ninety seconds or slower than three feet in one hundred and thirty seconds, shall be used in any mine.

COMMENT:—Accepted brands of fuse range within these limits.

Rule 47. (64.) No fuse shall be used in any mine unless the rate of burning be legibly marked by the manufacturer on each package.

COMMENT:—This change is suggested to conform to other rules bearing on this subject.

Rule 48. (65.) Notice shall be posted at the main entrance of every mine stating the rate of burning of the fuse used in such mine. The superintendent shall be responsible for the carrying out of this rule.

SECTION 37—(Continued).

GENERAL RULES.

Rule 66. No person in a state of intoxication shall be allowed to enter or loiter about a mine.

Rule 67. All employees shall inform the mine foreman or his assistant of the unsafe condition of any working place.

Rule 68. Wages shall not be paid on any premises used for the sale of intoxicating liquors.

Rule 69. No intoxicating liquors shall be taken into a mine.

Rule 70. Strangers or visitors shall not be allowed underground in any mine unless accompanied by the operator or an official of the mine, or by an employee deputized by such operator or official to accompany them.

Rule 71. Every mine employing more than twenty-five men shall maintain a suitably equipped wash room which shall at all times be open to the employees of the mine.

Rule 72. Each workman employed in the mine when engaged shall have his attention directed by the mine foreman to the general and special rules provided for in this Act.

Rule 73. Any person who does any act wilfully in violation of any of the rules as prescribed in this Act shall be guilty of a misdemeanor.

SECTION 35. (37)—(Continued).

COMMENT:—Some of our Committee think that this rule should be deleted, as unnecessary.

COMMENT ON RULES (66, 68 AND 69):—Since Section (47) embraces the matter of Rules 66, 68 and 69, we have slightly modified the section so as to cover all the matter of these three rules, and would delete the rules because, as written, they do not invoke the police power of the State for their enforcement, while under Section No. 44 (47) this police power is clearly invoked, which we think is necessary.

However, if it be regarded preferable to have the subject of intoxicating liquors in the form of rules we would place them under a caption **Intoxicating Liquors Prohibited in Mines.** By the addition of the phrase "or any of the buildings connected with the operation of the same within this State" at the end of Rule (66), and the addition of the paragraph, "Provided however................therein" the three rules would cover the entire subject.

Rule 49. (67.) Every employee shall immediately inform the mine foreman or his assistant of any unsafe condition within the mine which may come to the attention of such employee.

Rule 50. (70.) Strangers or visitors shall not be allowed underground in any mine unless accompanied by the operator or an official of the mine, or by an employee designated by such operator or official to accompany them.

(71.) COMMENT:—While nearly always desirable to have washrooms, it is seldom of such necessity as to justify the use of the police power of the State; in view of the serious difficulties in high altitudes and in arid regions.

(72.) COMMENT:—Since it is required that a copy of this law shall be posted at every mine, and since ignorance of the law never excuses from its penalties, we recommend deletion of this rule.

(73.) COMMENT:—Because this subject is thoroughly covered under Section 45 (48) entitled **Penalties** we would delete here.

Sec. 38. TWO OPENINGS TO SURFACE.

It shall be the duty of every operator of every mine within this State, excepting as hereinafter provided, to maintain at least two outlets to the surface from such mine; or an underground communicating passage way between every such mine and some other contiguous mine, so that there shall be at all times at least two distinct and available means of access to the surface to all persons employed in such mine or mines. Such outlets shall not be less than 50 feet apart and shall, if covered, be provided with separate and distinct and non-connecting houses on the surface.

Where two openings to the surface shall not have been provided as aforesaid, it shall be the duty of the Inspector of Mines to order in writing, served upon the operator or superintendent of such mine, a second opening to be made without delay by the operator of said mine, and in the event of the operator of such mine failing forthwith to commence and prosecute the making of a second opening within twenty days after the service of said order, or in the event of the Inspector deeming any mine having but one such opening to be dangerous to the lives and health of those employed therein, it shall thereupon be the duty of such inspector forthwith to institute an action for an injunction to close said mine, provided for in Section 12 of this Act.

Provided, however, that Section 38 of this Act shall not apply in the case of (A) New workings being opened for the purpose of making a communication between two or more shafts, or to any working for the purpose of searching for or proving ore; (B) Or to any mine in which one of the shafts or outlets has temporarily become unavailable for the persons employed in the mine, and in which every effort is being made by the operator of the mine to open such temporarily unavailable outlet, and provided the same is not, in the opinion of the Inspector dangerous to the life and health of those employed therein; and (C) Mines having workings of less than 100 feet in depth.

SECTION 36. (38.) TWO OPENINGS TO SURFACE.

It shall be the duty of the operator of any mine within this State, excepting as hereinafter provided, to maintain at least two passageways to the surface from such mine; or an underground passageway between such mine and some other mine, so that there shall be at all times at least two distinct and available means of access to the surface for all persons employed in such mine or mines, both of which shall be independent of any mechanical means of transport. Any part of such passageways having an inclination of more than thirty-five degrees from the horizontal shall be provided with substantial ladders. The outlets shall not be less than fifty feet apart, and any buildings covering them shall be distinct and separate.

Where two passageways to the surface shall not have been provided as aforesaid, it shall be the duty of the inspector of mines to order in writing, served upon the operator or superintendent of such mine, that a second passageway be made without delay, and in the event of the operator of such mine failing forthwith to commence and prosecute the making of a second passageway within twenty days after the service of said order, the inspector is hereby authorized and directed to close such mine until such time as the requirements of this section shall have been met.

Provided, however, that this section shall not apply in the case of (A) new workings being opened for the purpose of making a communication between two or more shafts, (B) any mine in which one of the shafts or outlets has temporarily become unavailable for the persons employed in the mine, and where every effort is being made by the operator of the mine to open such temporarily unavailable outlet, and provided the same is not, in the opinion of the inspector, dangerous to the life and health of those employed therein; and (C) mines having workings of less than 100 feet in depth.

COMMENT:—The changes made are: In the first paragraph, to include a provision taken from Section (42); in the second paragraph to

Sec. 39. OPENINGS THROUGH CONTIGUOUS MINES. ALL COMMUNICATING OUTLETS BETWEEN CONTIGUOUS MINES SHALL BE ESTABLISHED BY AGREEMENT BETWEEN THE OWNERS THEREOF.

When communicating outlets have been established between contiguous mines, it shall be unlawful for the operator of either mine to close the same without the consent of both the contiguous operator or owner, and the Inspector of Mines.

Provided, however, that when such contiguous outlets have been established, each operator, unless it shall have been otherwise provided by agreement, shall pay a fair proportionate share of keeping such openings in such condition that men working in such contiguous mines may have access to the surface thereby.

Provided, further, that in the event of either operator desiring to abandon mining operations, the expense and duty of maintaining such communications shall devolve upon the party continuing operations and using the same.

In the event of failure or refusal on the part of one contiguous operator to keep such opening in safe condition, the other contiguous operator shall have access thereto for the purpose of repairing and maintaining the same. When operators of contiguous mines have, by agreement, established underground communications between said mines as escapement outlets for the men employed in both, it shall be the duty of each operator to cause such communicating outlets in each operator's mine to be inspected at least once in every twenty-four hours; and it shall be the duty of each operator to see to it, within their respective mines, that the same are kept clear of every obstruction to travel and that intervening doors, if any, shall be kept unlocked and ready at all times for immediate use.

provide for the inspector closing a mine instead of instituting a suit (this is in harmony with the provisions suggested for Section 21 (23) and for the reason there stated); in the third paragraph we believe that the elimination of line four is required, since its retention seems to practically nullify the whole section.

SECTION 37. (39.) OPENINGS THROUGH CONNECTING MINES.

When communicating outlets have been established by mutual consent between mines, it shall be unlawful for the operator of either mine to close the same without the consent both of the other operator or owner, and of the Inspector of Mines.

It shall be the duty of each operator to see that the portion of the passageway within his mine is kept clear of every obstruction to travel and that intervening doors, if any, are kept unlocked and ready at all times for immediate use.

In the event of failure or refusal on the part of one operator to keep such opening in safe condition, the other shall have access thereto for the purpose of repairing and maintaining the same.

When such outlets have been established, each operator, unless it shall have been otherwise provided by agreement, shall pay a fair proportionate share of the cost of maintaining such passageway in condition for use.

In the event of either operator suspending mining operations, the expense and duty of maintaining such communications shall devolve upon the party continuing operations and using such communicating outlet.

COMMENT:—We think that in the heading and also in the text, that the word "Contiguous" should be changed to "Connecting", because connections are frequently made between mines which are not contiguous. We have also suggested other changes in this section.

We believe it would be unreasonable to forbid the operator of a mine to close an outlet which may have been established without his knowledge or permission. This section should apply only to cases where such connections have been deliberately made, by mutual consent of both operators, for the express purpose of affording outlets.

Sec. 40. PROVISIONS AFFECTING MINES HAVING BUT ONE OUTLET.

In every mine within this State, where under the provisions of Section 38 of this Act but one outlet is required, and where a single shaft affords the only means of ingress or egress to persons employed underground, such shaft if more than 200 feet deep shall be divided into at least two compartments. One of said compartments shall be set aside and used exclusively as a ladderway. Whenever such ladderway compartment shall be covered by a non-fireproof building, it shall be the duty of the operator of said mine to cause said ladderway to be securely bulkheaded at a point at least 25 feet below the collar of the shaft; and below this bulkhead, if the shaft is situated upon a side hill, a drift shall be driven to the surface; if the shaft containing said ladderway be otherwise situated this drift shall be driven on a level to a safe distance, but in no case less than 30 feet beyond the walls of the building covering the main shaft, and from such point a raise shall be made to the surface. The said raise shall be equipped with a ladderway, and it together with the drift connecting with the main shaft shall be kept in good repair and shall afford an easy exit in the event of fire. A failure on the part of the operator of said mine to carry out or cause to be carried out the provisions of this Section shall constitute a violation of this Act.

(40.) COMMENT:—We believe that the attempt to fix an arbitrary depth at which these provisions will apply is a mistake, and that there is a better and a more natural way of reaching the same end, for the following reason:

As long as a shaft is operated by a windlass ("human power") the whole length (of any ordinary shaft) is required for the bucket. It is unreasonable and impracticable to attempt to say that a miner must stop hoisting by human power at any given depth. There is no danger of windlass hoisting going to an excessive depth. On the other hand, as soon as hoisting begins with other than human power (a whim is fully as dangerous as a steam hoist) the shaft should be partitioned, even if only fifty feet deep; and as soon as a separate manway compartment is made it should have, and might as well be required to have, the platforms and inclined ladders. This point was mentioned by Mr. Chance in discussion in November, 1910. When platforms are put in, the ladders can be changed from vertical to inclined at the same time and with practically no additional expense.

The language "used exclusively as a ladderway" is somewhat objectionable, since all piping, electrical wiring, etc., are usually put in the manway compartment.

The condition "if the shaft is situated upon a side hill" is vague, since few mine shafts are on level ground; and the specific provision for driving a level and a vertical raise is uncalled-for and awkward. The only necessary provision is that the safety outlet shall reach the surface 30 feet beyond the building. The very best form for such outlet would often be a slope.

We would write this section as follows:

SECTION 38. (40.) PROVISIONS AFFECTING MINES HAVING BUT ONE OUTLET.

In every mine within this State, where under the provisions of section 36 of this Act but one outlet is required, and where a single shaft affords the only means of ingress and egress to persons employed underground, such shaft, if hoisting therein is done by other than human power, shall be divided into at least two compartments, one of which shall be used as a ladderway, and shall be equipped with platforms and inclined ladders as provided in Section 35, Rule 25.

Whenever such ladderway compartment shall be covered by a non-fireproof building, it shall be the duty of the operator of said mine to cause said ladderway to be provided with a bulkhead, and with a door, at least 25 feet below the collar of the

Sec. 41. OUTLETS NOT TO BE COVERED BY HOUSES.

It shall be unlawful for the operator of any mine within this State, after the passage of this Act, to erect any structure over the shaft or outlet of any mine, except head frames necessary for hoisting from such shaft or outlet, and the hatch or door necessary for closing such shaft or outlet.

Provided, however, it shall be lawful to erect a housing of non-inflammable and fireproof material over such shaft or adit to protect the men working at such point. In the case of existing houses covering the mouths of shafts or adits, it shall be the duty of the Superintendent of the mine to cause the immediate removal of all inflammable material stored therein, and it shall be the further duty of such Superintendent to prohibit the storage of any inflammable material within thirty feet from the exterior walls of any such existing house or within a like distance from the walls of any housing hereinafter built under the provisions of this Section. A failure on the part of any such superintendent to enforce the provisions of this Section relative to the storage of inflammable materials, shall be deemed a violation of this Act.

It shall be the duty of every operator to provide every adit, the mouth of which is covered by a house or building of any kind, with a door near the mouth of the adit, that can be closed from outside of the building by a pull wire or cable in the event of fire.

shaft, and below the natural surface; and below this bulkhead a passageway shall be driven to the surface, in no case less than 30 feet beyond the walls of the building covering the shaft. The said passageway shall be kept in good repair and shall afford an easy exit in the event of fire.

A failure on the part of the operator of said mine to comply with the provisions of this section shall constitute a violation of this Act.

NOTE:—Rules (37) and (52) of Section (37) require to be modified to conform to the provisions of this section, both substituting the condition of power hoisting in place of the arbitrary 100 feet in depth.

SECTION 39. (41.) BUILDINGS COVERING OUTLETS.

Whenever the mouth of a shaft or outlet from a mine is covered by a combustible building of any kind, it shall be the duty of the superintendent to see that no oils, candles or other inflammable stores are kept inside such building, or within a distance of thirty feet from the exterior walls thereof.

It shall be the duty of every operator to provide every shaft or adit, the mouth of which is covered by a building of any kind, with a substantially air-tight door near the mouth of the shaft or adit, which can be closed from outside of the building by a pull wire or cable, in the event of fire. In case of adits connecting with the surface by shaft or raise, there shall be two doors, one near the entrance and the other between the entrance and such shaft or raise, both of which doors shall in no case be permitted to be open at the same time, except when the draft shall be towards the mouth of such adit; such door, in case of shafts, shall be above the outlet provided for in section 38 (40), and in case of adits, shall be of fireproof construction together with its settings, or shall be isolated from such building by a space of at least thirty feet, in which space there shall be no inflammable material.

Sec. 42. LADDERWAYS AND LADDERS.

It shall be the duty of the operator of every mine to provide in addition to any mechanical means of ingress or egress, at least one means of outlet for the miners by means of ladders, from the lowest workings of the mine to the surface. All ladders and ladderways, constructed after the passage of this Act, shall be built as prescribed in Rules 35 to 42 of Section 37 of this Act. All floors of setts in stopes and every shaft, winze, raise or incline steeper than 35 degrees from the horizontal through which men are obliged to pass, shall be provided with ladders and ladderways as specified in this Section.

(42.) LADDERWAYS AND LADDERS.

COMMENT:—Since Sec. (37), Rules (35-42), is headed, **Ladders and Ladderways** we suggest that another section **Ladderways and Ladders** is not necessary, and that all that is new in this section naturally falls under Section 35 (37), therefore, by the addition of the phrase "both of which shall be independent of any mechanical means of transport," and the addition of a sentence relating to inclines of more than thirty-five degrees, which we have made in Section 35, together with the provisions of Rules 25-29 (35-42) of Section 35, as amended, and Section 38 (40), as amended, this section becomes unnecessary and should be deleted. Otherwise Rules (35 to 42) of the original draft should be deleted and their substance included in a section with the same caption.

SECTION 40. FIRE PROTECTION.

(See (37) Rules 5 and 6).

Wherever, in the opinion of the inspector, the timbering, the nature or position of surface buildings, or the character of the equipment employed, might result, in case of fire, in smoke or fumes such as would imperil life, the Inspector of Mines may designate such mine or part of mine as inflammable, and require the following special rules:

A. No candle shall be left burning in any part of the mine when the person using the candle departs from his work for the day, unless such candle is protected by a suitable sconce.

B. The operator or superintendent of the mine shall provide and keep in a readily accessible place, at least two fire fighting helmets.

C. The operator or superintendent of the mine shall provide sufficient fire protection in the form of water lines or fire extinguishers.

A minority of the committee, while agreeing to the substance of the above draft, would consider it safer to first lay down the rules A, B, and C, and then allow wet mines to be exempt from their operation by permission of the inspector. This would relieve the inspector of a certain amount of responsibility, and protect mines which might otherwise be overlooked.

Sec. 43. VENTILATION.

The operator of every mine, whether operated by shaft, stope or drift, shall provide and maintain for every such mine a good and sufficient amount of ventilation for such men and animals as may be employed therein, and shall cause an adequate amount of pure air to circulate through and into all the shafts, winzes, levels and all the working places of such mine.

SECTION 41. (43.) VENTILATION.

The operator of every mine shall cause an adequate amount of air to circulate through all the working places of such mine.

COMMENT:—We have carefully considered the advisability of attempting to establish by law a definite standard of purity to be required of air in mines, based on maximum allowable percentage of CO and CO_2, or on minimum percentage of oxygen; and have arrived at the conclusion that, under the varying conditions of small vein mines, no uniform standard is possible. We cannot hope to raise the level of mine supervision sufficiently to depend on the ordinary superintendent and foreman to make the rather delicate tests necessary; and even in the best-conducted mines certain places, such as levels and raises which are being driven for the purpose of making air connections, are bound to contain air of a purity far below the minimum which ought to be required of the other portions. Moreover, it would be unfair to require of mines in which the rock emits gas, particularly at periods of low atmospheric pressure, the same minimum standard. The effect of such a provision would merely be to inflict an undeserved handicap on the more careful and conscientious operators. We conclude that this is one more case in which wide discretionary powers must be given to the Inspector of Mines.

SECTION 42. (NEW.) PREVENTION OF DUST.

The use of compressed air, without water, to expel the cuttings from dry holes while they are being drilled by machine drills, is prohibited.

In dry dusty stopes or raises where machine drills are employed it shall be discretionary with the Mine Inspector to require the use, either of some approved device for collecting, spraying or wetting the dust, or the wearing by the drill-men of approved respirators; and any superintendent who shall neglect or refuse to provide such collecting or spraying or wetting device or respirators, within one month after having been notified in writing so to do by the Inspector of Mines, or any miner or other person who shall wilfully and continuously neglect or refuse to use the same, after they shall have been provided by the superintendent, shall be guilty of a violation of this Act.

Sec. 44. SANITATION. DRY CLOSETS.

It shall be the duty of the operator of every mine, for the purpose of improving the sanitation thereof, and preserving the health of those employed therein, to provide dry closets for the use of all men employed in such mines. At least one of such closets shall be placed on every level where an average of twenty-five or more men are employed, at any one time, and at least one such closet shall be provided for every twenty-five men employed within such mine. No dry closet shall be constructed without adequate provision for the effectual cleansing and removing of the contents thereof, which shall be removed and disposed of from time to time. It shall be the duty of the Mine Foreman to cause each dry closet to be supplied with some disinfectant or deodorizer to be sprinkled upon the contents thereof. It shall be the duty of all men employed within any mine where such closets are provided to use such closets exclusively when in the mine. Any operator of any mine who shall neglect or fail to provide closets, as required in this section, for use in any such mine, shall be deemed guilty of a violation of this Act.

COMMENT:—This Act being intended to provide for preservation of health as well as prevention of accidents in mines, we think it imperative to include some provision to lessen the worst causes of the dust which produces the disease of silicosis or miners' consumption. If this Act makes no such provision, it is more than probable that very radical and onerous laws on the subject will be introduced in the legislatures of various States. Very much more stringent laws have been adopted in South Africa and other English-speaking countries.

We have carefully considered this section, and suggest its adoption as likely on the one hand to remove the worst dangers, and on the other to prove no serious burden to any mine.

SECTION 43. (44). SANITATION. DRY CLOSETS.

It shall be the duty of the operator of every mine to provide dry closets for the use of all men employed therein. At least one of such closets shall be placed on every level where an average of twenty-five men is employed at any one time, and at least one such closet shall be provided for every twenty-five men employed within such mine. Adequate provision shall be made for effectually disinfecting and cleansing such closets, and for frequently removing and disposing of the contents.

Provided, however, that this section shall not apply to mines, or parts of mines, from which employees can at all times reach the surface within fifteen minutes, and *provided further,* that access to a waterway in an adit, containing a permanent flow of water which, in the opinion of the Inspector of Mines, is sufficient to render it an effectual sewer, shall be regarded as the equivalent of access to the surface, for the purposes of this section.

Any operator of a mine who shall fail to make provision for dry closets or access to surface as provided in this section, or any person who shall stool underground, excepting in the places provided for the purpose, shall be guilty of a violation of this Act.

COMMENT:—We have redrafted this section, because we find that underground closets are at best a makeshift and a nuisance. Where access to surface can be conveniently had, it is far preferable to the use of dry closets. Similarly, a good permanent flow of water in an adit is far more satisfactory from a sanitary point of view than a dry closet. In Western mines it is a difficult thing to enforce proper cleansing of the latter—unless

Sec. 45. ROOF INSPECTION.

In all mines where stoping is done by the opening of chambers, the roof thereof being supported only by the walls of the chambers, or by pillars, it shall be the duty of the superintendent of the mine to detail a competent man to make a frequent inspection of the roof of those parts of the mine where men are employed, and said man so detailed shall be charged with the duty of dislodging any slabs of rocks in said roof which have become loose. While such dislodgement is being affected the floor of the stope immediately beneath such loose rock shall be fenced off, or otherwise adequately guarded.

Sec. 46. SAFETY PILLARS.

It shall be the duty of the operator of every underground mine to leave standing on the inside of the boundary line of every mining property, safety pillars the width of which must not be less than 30 feet, measured at right angles from the said boundary line.

Provided, however, that on the application of either owner of adjoining mines, the Inspector may give permission in writing to either or both owners to weaken, cut through or work such pillars, if in the opinion of the Inspector the same will not be dangerous to the lives of those employed within either of said mining properties. Such consent, or a copy thereof, shall be filed in the office of the Inspector. The failure of the operator of either or both of such adjoining mining properties to observe the provisions of this Section, shall be deemed a violation of this Act.

the foreman or superintendent is to attend to the job personally. In mines where the workings are scattered, so much difficulty is experienced in compelling men to observe sanitary regulations, that we think the law should specifically make it an offense for miners to commit a nuisance underground.

(45.) ROOF INSPECTION.

COMMENT:—In the opinion of the committee this section should be eliminated, because it goes far beyond reasonable limits for any general law.

On surface, in shafts and in main roads, there is a similarity of conditions existing in all mines, and there is little about mine conditions at these places that marks off mining from manufacture, and general laws may go into detail, as in the case of factory inspection laws.

There are large mines where the stopes and other workings are of a character to continue factory conditions, and make possible what is akin to factory supervision; in such cases it is right that the unskilled labor should look for safety from the "roof-inspector." But in the commonest mines only the skilled miner goes from the main roads alone or in small groups, to individual places of work, and there picks down roof and walls for his own safety; it is the place where he worked yesterday and expects to work tomorrow, and he knows the peculiar conditions better than any other. To attempt to put the care of the roof in such workings upon a special inspector, and relieve the individual of his responsibility, would have a most unfortunate effect in lessening the already too low sense of responsibility among miners, and, further, in putting an impossible burden of responsibility on the operator. The rule seems unnecessary. That roof must be picked down is axiomatic; how it shall be picked down is a special study for each mine, and no general rule can be otherwise than mischievous.

(46.) SAFETY PILLARS.

COMMENT:—We recommend the omission of this section because of insuperable difficulties arising out of extralateral rights; and because the security it would offer is sufficiently provided for in Sec. 21 (22), and Sec. 35 (37), Rules (32-34), as we have redrafted them, as Rule 22.

In some cases, nothing short of a Court of last resort can decide what is the boundary line of any mining property. Where claims are small or fractional, but temporarily consolidated for working under one management, it would be a serious hindrance to working to require a 30-foot pillar on the inside of every boundary-line. In the case of narrow claims, where a vein successively dips below various side-lines, it would be unreasonable to require safety-pillars at every such boundary-line.

Sec. 47. INTOXICATING LIQUOR PROHIBITED IN MINES.

Whoever shall, while under the influence of intoxicating liquor, enter any mine, or any of the buildings connected with the operation of the same within this State, where miners or other workmen are employed, or whoever shall carry intoxicating liquors into the same, shall be deemed guilty of an offense against this Act, and upon conviction shall be punished accordingly.

Provided, however, nothing herein contained shall prevent the carrying of any alcoholic spirits or liquor into such mine or buildings for the purpose of administering to any one injured therein.

Sec 48. PENALTIES.

Any wilful neglect, refusal or failure to perform the duties imposed and required to be performed by any section, clause, provision or rule of this Act, on the part of the parties or persons therein required to perform them, or the violation of any of the provisions or requirements thereof, shall be deemed a misdemeanor punishable by a fine not exceeding five hundred dollars, or by imprisonment for a period not exceeding six months, or both, at the discretion of the Court.

For any injury to person or property, occasioned by any wilful violation of this Act, or wilful failure to comply with any of its provisions, by any owner, operator, or superintendent of any metalliferous mine or quarry within this State, employing at least ten men, a right of action shall accrue to the party injured, for any direct damages sustained thereby, against said owner or operator, and in case of loss of life by reason of such wilful violation and wilful failure, as aforesaid, a right of action shall accrue to the widow and lineal heirs or adopted children of the person so killed, for a like recovery for damages for injury sustained by reason of such loss of life, not to exceed the

SECTION 44. (47.) INTOXICATING LIQUOR PROHIBITED IN MINES.

Whoever shall, while under the influence of intoxicating liquor, enter any mine, or any building connected with the operation of any mine within this State, or whoever shall carry intoxicating liquors into the mine or into the immediate vicinity thereof, or whoever shall pay wages on premises used for the sale of intoxicating liquors, shall be guilty of a violation of this Act.

Provided, however, nothing herein contained shall prevent the carrying of any alcoholic spirits or liquor into such mine or building for the purpose of administering the same to any sick or injured person therein.

See Comment under original rules 66, 68, and 69.

SECTION 45. (48.) PENALTIES.

Any wilful neglect, refusal or failure to perform the duties imposed and required to be performed by any section, clause, provision or rule of this Act, on the part of the parties or persons therein required to perform them, or the violation of any of the provisions or requirements thereof, shall be deemed a misdemeanor punishable by a fine not exceeding five hundred dollars, or by imprisonment for a period not exceeding six months, or by the disqualification, permanent or temporary, of any inspector, deputy inspector, superintendent, foreman or hoisting engineer from acting in any such capacity within the limits of this State; or, any or all of such penalties together.

For any injury to person or property, occasioned by any wilful violation of this Act, or wilful failure to comply with any of its provisions, by any owner, operator or superintendent of any mine within this State, a right of action shall accrue to the party injured, for any direct damages sustained thereby, against said owner or operator, and in the case of loss of life by reason of such wilful violation and wilful failure, as aforesaid, a right of action shall accrue to the widow and lineal heirs or adopted children of the person so killed, for a like recovery for damage for injury sustained by reason of such loss of life, not to exceed sum of Five Thousand Dollars. Provided that all suits brought under this section shall be commenced within one year from the time any cause of action shall have accrued under this section, and not afterward.

Sec. 49. COPY OF ACT TO BE POSTED.

It shall be the duty of the superintendent of every mine within the provisions of this Act to post or cause to be posted, at all times, in the office of said mine, and on a building or board in some conspicuous place at each entrance to the mine, a printed copy of this Act.

Any person who wilfully removes, injures or defaces any such printed copy, when so posted, shall be guilty of a violation of this Act.

Sec. 50. REPEAL OF INCONSISTENT LAWS.

All laws or parts of laws inconsistent with the provisions of this Act are hereby repealed.

Sec. 51. ACT TO TAKE EFFECT.

This Act shall take effect on the —— day of ————, 19 .

(N. B. At least ninety days after the passage of the Act, so as to prepare the miner and operator to the changed conditions.)

the sum of five thousand dollars. Provided that all suits brought under this section shall be commenced within one year from the time any cause of action shall have accrued under this section, and not afterward.

SECTION 46. (49.) COPY OF ACT TO BE POSTED.

It shall be the duty of the superintendent of every mine within the provisions of this Act to post or cause to be posted, at all times, in the office of said mine, and on a building or board in some conspicuous place at each main entrance to the mine, a printed copy of this Act.

Any person who wilfully removes, injures or defaces any such printed copy, when so posted, shall be guilty of a violation of this Act.

SECTION 47. (50.) REPEAL OF INCONSISTENT LAWS.

All laws or parts of laws inconsistent with the provisions of this Act are hereby repealed.

SECTION 48. (51.) ACT TO TAKE EFFECT.

This Act shall take effect on the ——day of ———— 19—.

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THE EFFECTS OF DEFOLIATION AND THE APPLICATION OF NITRATES ON THE COMPOSITION OF THE SUGAR BEET.

By Dr. William P. Headden.

(Read at the meeting of the Society, December 7, 1912.)

Introduction.

In prosecuting the study of the cause of the deterioration in the quality of sugar beets[1] grown in some sections of Colorado, but particularly in the Arkansas Valley, it became necessary to determine in the most conclusive manner possible what is the probable effect of *Cercospora beticola* upon the composition of the beet. The attack of this fungus on the beets grown in this valley is often so severe that it kills a very large percentage of the leaves, sometimes it removes practically the whole of the foliage.

There is no doubt entertained about the deterioration in the quality of the beets during the past eight years. The *Cercospora beticola* has been more or less prevalent during the greater part of this period and its effects upon the foliage of the beets has some years been nothing less than disastrous. This result is very apparent and striking. It apparently furnished a ready explanation which, because of its very evident effects upon the foliage, seemed wholly sufficient, at least to some, to account for the poor quality of the crops produced.

It is not for a moment questioned but that the destruction of from 60 to 90 per cent. of the foliage of the beet, usually in the month of August, has a serious effect upon the crop produced but it is not evident that these effects are identical with the general deterioration which we made the object of our study. This seems to be a question of composition in a different sense, in other words it seems to me to be a question of nutrition rather than one of suspending, impairing or destroying the function of some portion of the plant by physical means. There is no question about the *Cercospora* having killed a very large portion of the leaves, especially the older fully developed ones; there may, however, be a question whether this fungus affects the plant in any other way than by doing it a simple, physical injury.

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[1] Bulletin 183. Colorado Experiment Station.

HISTORICAL.

The effects of removing the leaves from sugar beets have been studied by a number of investigators who have agreed in stating the results in terms of the yield of roots, the yield of sugar and of dry substance. Andrlik and Urban[2] state the effects of removing 70 per cent. of the leaves in the early part of July to have been a depression of 36 per cent. in the yield of beets, 35 per cent. in the yield of sugar, and 34 per cent. in the yield of dry substance. The defoliated plants removed much less plant-food: 38·8 per cent. less nitrogen, 34·9 per cent. less potash and 36·0 per cent. less phosphoric acid than uninjuried plants. Experiments made in the latter part of July and in August gave the same kind of results but they differed in degree. The degree of the injury done varied, too, with the extent of the defoliation. Strohmer, Briem and Fallada[3] have also recorded experiments for the purpose of showing the effects of defoliation. These investigators assert that the effects of total defoliation depend upon the development of the plant at the time of defoliation, if this be made just prior to the period of the most active sugar production by the leaves, in the early part of July, the injury will be much more serious than if the defoliation takes place subsequent to this period, in the latter part of August. Their results agree with those obtained by other experimenters in showing that these effects are to reduce the yields of roots, sugar and dry substance. Defoliation on July 12 reduced the yield of roots 37·0 per cent. and the yield of sugar 36·0 per cent.; on July 30, the yield of roots by 46·0 and that of sugar 43·3 per cent.; on August 24, the yield of roots 23·0 per cent. and that of the sugar 25·4 per cent. The results recorded as produced by partial defoliation are not concordant and the reasons are not evident, but doubtless the factors already indicated, the development of the plant at the time of defoliation and its extent, play important parts.

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[2] Jahresbericht der Zuckerfabrikation 1907, p. 55.

[3] Jahresbericht der Zuckerfabrikation 1908, p. 33.

FIELD OBSERVATIONS UPON DEFOLIATION DUE TO CERCOSPORA BETICOLA.

Observations made on 127 fields of beets, aggregating about 2,500 acres, did not convincingly show that the leaf-spot had produced any depression in the yield of beets; and the average sugar content, ascertained by taking the average of several thousands of determinations, was only 0·3 per cent. below the total average of the season based on more than 250,000 tons of beets. The extent of defoliation in these 127 fields varied greatly, in some cases it was nearly complete, in others it was much less, perhaps from 40 to 50 per cent. No clear, persistent and concordant relation could be found between the severity of the attack and the yield or quality of the beets, leaving it wholly doubtful as to what degree of responsibility for the general deterioration of the beets might justly be attributed to this disease. The assumption is made that this disease produces no other effects than those produced by defoliation, which may not be fully justified; but there is no evidence that it is not.

The deterioration which has taken place in the beets grown in the Arkansas Valley cannot be said to consist in a falling off of the yield of beets, for the average yield of beets for 120 fields in 1910, when the leaf-spot was very bad, was 11·4 tons which is quite as high as the average of other districts, even in sections where the leaf-spot had done no damage. It has already been stated that the average percentage of sugar in these beets was about 0·3 per cent. below the general average of the entire crop of the valley. The factory data do not, of course, include the percentage of dry substance. This factor, however, is comparatively low, but for the present the cause of this fact may be left wholly out of consideration.

Artificial Defoliation.

If the effects of the leaf-spot be the same as those of defoliation, then we should have very decidedly lower yields and lower percentages of sugar than in normally developed beets. The data obtained by observation of the results obtained in 127 cases left these questions in the greatest uncertainty. These data, as we were able to obtain them, were not satisfactory—besides the further changes produced in the composition of the beets had not been studied so far as the literature at our disposal showed. It remained then to determine the changes which are actually produced by defoliation; for this purpose beets of two varieties were defoliated on September 6. At this time the beets were well developed, the foliage was exceedingly heavy and the whole plant was growing vigorously. The defoliation was effected by cutting off all of the leaves, care being taken not to injure the crowns of the beets. The general results were a depression of the crop by 25·0 per cent., of the yield of sugar by 35·7 per cent. in one variety and still more in the other variety, and of the dry substance 30·0 per cent. It has already been stated that the beets were growing vigorously at the time of defoliation and the defoliation itself was complete, so that whatever foliage developed subsequent to this time was new foliage. The other beets were also putting out new leaves, and it is not determined whether these defoliated beets put out more leaves during the rest of the season than the other beets, or continued the purely vegetative function to a greater extent than those or not. This would, of course, postpone the period of maturation and perhaps produce the observed results. Whether this be the case or not the plants were deprived of the use of the foliage which should have carried on the normal functions of the plants and we may in a general way at least attribute the differences in the composition of normally developed beets and of those which had been defoliated to the work which the leaves would have done, had they not been removed. It is evident that we need further and different data than those already given to judge of these effects.

APPLICATION OF SODIUM NITRATE TO SOIL.

The bigger problem that was being studied, of which this particular subject was a subordinate study, was the effects of nitrates upon the composition and consequently upon the quality of the sugar beet. The results of this study are recorded in Bul. 183, of the Colorado Experiment Station.[4] In this work special attention was paid to the nitrogen compounds and to the ash constituents in the beets as it was thought that the quality of the beets was determined by the supply of nitrates at their command and that the nitrates could be traced in the various parts of the plant, in the roots, in the petioles and in the blades of the leaves. For the accomplishment of this purpose, the total nitrogen, the proteid nitrogen, and the nitric nitrogen were determined in the blades and petioles; the total, proteid, ammonic, amid, amino and nitric nitrogen in the beets; and the total, albumin, propetone and peptone nitrogen in the juices of the beet. The proteid nitrogen in the blades and petioles of the leaves and in the beets was determined by Stutzer's method which gives rather high results but the albumin nitrogen in the juices of the beets was precipitated by means of acetic acid, alcohol, and ether.

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[4] Headden, Wm. P. Deterioration in the Quality of Sugar Beets Due to Nitrates Formed in the Soil. Colo. Expt. Sta. Bul. 183 p. 122. 1912.

The results are given in the following analyses in which the letters ER and ZR indicate different strains of beets.

ANALYSIS OF BEETS AND LEAVES.

	September 1		*October 12*	
Variety	*ER*	*ZR*	*ER*	*ZR*
Av. weight of beets, grams.	625·3	510·3	894·6	759·2
Av. weight of leaves, grams	735·6	614·3	812·7	648·9
Av. wt. tr'm'd beets,[5] grams.	543·4	469·4	768·6	617·0
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Sugar in beets	11·90000	13·20000	15·30000	15·80000
Dry substance in beets....	18·69000	19·76000	23·07000	23·05000
Dry substance in leaves....	10·03000	10·53000	11·30000	12·00000
Total nitrogen in beets....	0·13794	0·13068	0·14124	0·14388
Total nitrogen in blades...	0·56628	0·45102	0·57288	0·50952
Total nitrogen in stems....	0·10362	0·11418	0·15180	0·12938
Proteid nitrogen in beets..	0·07317	0·07418	0·07154	0·07497
Proteid nitrogen in blades.	0·45302	0·42530	0·35798	0·40656
Proteid nitrogen in stems..	0·07238	0·07340	0·10243	0·09134
Nitric nitrogen in beets....	0·01925	0·01670	0·00503	0·00870
Nitric nitrogen in blades...	0·00730	0·01096	none	none
Nitric nitrogen in stems...	0·03734	0·04816	0·01956	0·01797
	Beet Juices.			
Total nitrogen	0·11480	0·11639	0·11869	0·11030
Albumin nitrogen	0·03772	0·03742	0·04429	0·04576
Propetone nitrogen	0·61464	0·01156	0·00514	0·00245
Peptone nitrogen	?	?	0·00087	0·00685

These beets were grown in good soil without fertilization of any kind so that the nitrogen compounds found in the plants were formed from the supply of assimilable nitrogen, nitrates, supplied by the soil during the growth of the plants. That the amount of these compounds varied with the supply in the soil is shown by the composition of samples of the same varieties of beets taken on the same date, October 12, from plots which had received applications of sodic nitrates equal to 750 pounds per acre, applied subsequent to August 1.

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[5] Trimmed beets are beets with the crowns removed as they should be for cutting in the factory.

Samples Taken October 12.—Sodic Nitrate Applied at the Rate of 750 Pounds Per Acre.

Variety	*EK*	*ZR*
Average weight of beets, grams	1,017·0	801·7
Average weight of leaves, grams	888·3	900·9
Average weight trimmed beets, grams	834·8	672·7
	Per cent.	*Per cent.*
Sugar in beets	14·40000	14·30000
Dry substance in beets	20·87000	20·04000
Dry substance in leaves	11·95000	11·41000
Total nitrogen in beets	0·16896	0·16368
Total nitrogen in blades	0·56496	0·54177
Total nitrogen in stems	0·17160	0·16764
Proteid nitrogen in beets	0·08368	0·08104
Proteid nitrogen in blades	0·37910	0·43428
Proteid nitrogen in stems	0·08447	0·09081
Nitric nitrogen in beets	0·01685	0·01685
Nitric nitrogen in blades	0·01208	0·01360
Nitric nitrogen in stems	0·04313	0·07967
Beet Juices.		
Total nitrogen	0·14622	0·15074
Albumin nitrogen	0·04796	0·04968
Propetone nitrogen	0·00319	0·00413
Peptone nitrogen	0·01905	0·00296

The first four analyses present the changes which took place in the nitrogen compounds of the plants between September 1 and October 12, in the plants with a very vigorous growth of leaves, as is shown by the average weight of leaves per beet; the last two show how these two compounds in the beets, leaves and roots, were affected by the application of nitrates up to the latter date, October 12. The dry substance in the leaves was not affected while the dry matter in the beets was materially lowered by the use of nitrates. The whole plant had increased greatly in weight, approximately 300 grams, in the case of each variety, but the total nitrogen had increased in percentage; this was true of the roots, petioles and blades, of the latter, however, in a less marked degree than in the two former. The percentage of the proteid nitrogen had not increased in the roots, had increased in the petioles and had decreased in the blades. The percentage of nitric nitrogen in the beets had fallen in the case of one variety to about one-fourth and in that of the other to about one-half of what it was on September 1, which is a much greater decrease than can be attributed to the increase in the size of the roots. The nitric nitrogen had entirely disappeared from the blades by September 28, but was still abundant in the petioles on October 12, though only about one-half as much so as it was on September 1. The analyses of the beet juices show that while the percentage of total nitrogen remained essentially the same, those for the albumin nitrogen increased materially. The general changes that had taken place in these plants were a marked increase in the total nitrogen which is true of the several parts, blades, stems and roots, a relative increase in the proteid nitrogen in the roots and stems and a decrease of it in the blades. There is a decided decrease in the amount of nitric nitrogen, it having entirely disappeared from the blade of the leaf as early as September 28, and having fallen in the roots from 0·01925 on September 1 to 0·00503 per cent. in one case, and from 0·01670 to 0·00870 per cent. in the other by October 12. There was also a fall of about one-half in the nitric nitrogen in the petioles. The nitric nitrogen in the petioles was uniformly found to be much higher than in either the blades or the beets. No samples of leaves were taken subsequent to October 12, because they were frozen before the taking of our next regular samples. The preceding statements do not apply to beets which had been treated with sodic nitrate, 750 pounds per acre applied in six separate portions. In this case the whole plant, blades, petioles and roots remained very rich in nitric nitrogen up to October 12.

EFFECTS OF ARTIFICIAL DEFOLIATION ON THE COMPOSITION OF THE BEET.

Samples of the defoliated beets were taken September 1 and November 8. No samples of leaves were taken subsequent to defoliation though there was a moderate development of them before they were frozen, perhaps one-half of a normal development but not one-half as many as the unmutilated beets of this crop had developed. The composition of these varieties as shown by samples taken September 1 and November 8 are given in the following tables:

	Normal Development	*Normal Development*	*Defoliated*	*950 pounds sodium nitrate per acre*
Variety	*ER*	*ER*	*ER*	*ER*
Date of Sampling	*Sept. 1*	*Nov. 8*	*Nov. 8*	*Nov. 8*
Ave. weight of beets, grams...	625·3	875·0	791·2	967·1
Ave. wt. trimmed beets, grams	543·4	747·0	701·0	819·3
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Sugar in beets	11·90000	15·60000	14·30000	14·60000
Dry substance	18·69000	21·16000	19·60000	20·21000
Pure ash in fresh beets	0·60735	0·54139	0·54440	0·55164
Sulphuric acid	0·02358	0·02561	0·02414	0·02495
Phosphoric acid	0·05425	0·05503	0·05380	0·04303
Chlorine	0·02314	0·01439	0·01933	0·01242
Sodium	0·01484	0·00936	0·01254	0·00808
Potassic oxid.................	0·31460	0·26141	0·26493	0·25865
Sodic oxid	0·09825	0·06370	0·06062	0·09844
Calcic oxid	0·02456	0·03342	0·03603	0·03006
Magnesic oxid	0·04813	0·07127	0·06775	0·06827
Ferric oxid	0·00329	0·00433	0·00178	0·00352
Aluminic oxid	0·00145	0·00087	0·00126	0·00170
Manganic oxid	0·00104	0·00192	0·00193	0·00252
Total nitrogen	0·13794	0·14882	0·12488	0·16632
Proteid nitrogen (Stutzer)....	0·07317	0·08474	0·06731	0·08646
Ammonic nitrogen	0·00251	0·00165	0·00105	0·00118
Amid nitrogen	0·00634	0·00593	0·00387	0·00771
Amino nitrogen...............	0·04150	0·05621	0·06267	0·05319
Nitric nitrogen	0·01925	0·00827	0·01367	0·01871
	Beet Juice.			
Total nitrogen	0·11480	0·13383	0·10178	0·14809
Albumin nitrogen	0·03772	0·05439	0·03639	0·05408
Propeptone nitrogen	0·01464	0·00489	0·00356	0·00737
Peptone nitrogen	?	0·00256	0·00444	0·00209
	Pure Ash.			
Sulphuric acid	3·883	4·731	4·533	4·523
Phosphoric acid	8·933	10·175	9·876	7·800
Chlorine	3·810	2·660	3·551	2·251
Sodium	2·477	1·729	2·309	1·464
Potassic oxid	51·794	48·285	48·636	46·888
Sodic oxid	16·176	11·766	11·129	17·846
Calcic oxid	4·044	6·174	6·617	5·450
Magnesic oxid	7·924	13·163	12·440	12·375
Ferric oxid	0·542	0·799	0·325	0·638
Aluminic oxid	0·245	0·161	0·230	0·308
Manganic oxid (br.)..........	0·172	0·357	0·354	0·457
Total......................	100·000	100·000	100·000	100·000

	Normal Development	*Normal Development*	*Defoliated*	*750 pounds sodium nitrate per acre*
Variety	*ZR*	*ZR*	*ZR*	*ZR*
Date of Sampling	*Sept. 1*	*Nov. 8*	*Nov. 8*	*Nov. 8*
Ave. weight of beets, grams...	510·3	929·3	701·3	1088·5
Ave. wt. trimmed beets, grams	469·4	784·4	590·0	951·0
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Sugar in beets................	13·20000	15·60000	13·20000	14·50000
Dry substance	19·70000	22·00000	19·27000	21·10000
Pure ash in fresh beets.......	0·55235	0·57223	0·58100	0·59255
Sulphuric acid	0·02341	0·02641	0·02462	0·02616
Phosphoric acid	0·06435	0·06256	0·06307	0·05584
Chlorine	0·01413	0·01721	0·02563	0·01312
Sodium	0·00917	0·01119	0·01666	0·00853
Potassic oxid	0·29742	0·28494	0·28042	0·29473
Sodic oxid	0·06676	0·06044	0·06624	0·08256
Calcic oxid	0·02140	0·03338	0·02808	0·03461
Magnesic oxid	0·05010	0·07201	0·07262	0·07154
Ferric oxid	0·00301	0·00193	0·00158	0·00172
Aluminic oxid	0·00162	0·00009	0·00092	0·00108
Manganic oxid	0·00098	0·00208	0·00117	0·00109
Total nitrogen	0·13068	0·14223	0·11286	0·16698
Proteid nitrogen (Stutzer)....	0·07418	0·08355	0·09029	0·08461
Ammonic nitrogen	0·00251	0·00171	0·00118	0·00258
Amid nitrogen	0·00568	0·00660	0·00343	0·00868
Amino nitrogen..............	0·04244	0·04982	0·05071	0·04775
Nitric nitrogen	0·01670	0·00746	0·01584	0·01421
	Beet Juice.			
Total nitrogen	0·11639	0·12314	0·09155	0·15119
Albumin nitrogen	0·03742	0·05292	0·03389	0·04858
Propeptone nitrogen	0·01156	0·00040	0·00273	0·00858
Peptone nitrogen	?	0·00947	0·00548	0·00663
	Pure Ash.			
Sulphuric acid	4·238	4·615	4·238	4·391
Phosphoric acid	11·651	10·932	10·855	9·423
Chlorine	2·559	3·007	4·410	2·214
Sodium	1·660	1·955	2·867	1·439
Potassic oxid	53·845	49·795	48·264	49·737
Sodic oxid	12·087	10·563	11·401	13·932
Calcic oxid	3·874	5·833	4·833	6·145
Magnesic oxid	9·071	12·583	12·499	12·073
Ferric oxid	0·545	0·337	0·271	0·283
Aluminic oxid	0·293	0·016	0·159	0·179
Manganic oxid (br.)..........	0·177	0·364	0·203	0·184
Total......................	100·000	100·000	100·000	100·000

The samples analyzed consisted of 18 beets each and represent the beets just before defoliation, normally developed, defoliated and such as had received applications of sodic nitrate equal in all to 750 pounds per acre. The last samples are included because it may fairly be questioned whether nitric nitrogen is present in beets grown under the best soil conditions or not, and in this connection it might be questioned whether it was defoliation or the presence of nitrates that produced the changes observable in the composition of the defoliated beets.

Assimilation of Nitrogen.

We have already seen the course of the changes taking place up to October 12 in the composition of the whole plant grown with and without addition of sodic nitrate, i. e., the total nitogen increased in the blades and petioles of the leaves and also in the roots; the proteid nitrogen increased in the roots and petioles but decreased in the blades. The nitric nitrogen disappeared from the blades of the leaves by or before September 28, and decreased materially in both the roots and petioles but was markedly higher in the latter than in the former, even on October 12, the latest date on which the leaves were analyzed. The effects of the nitrates applied were an increase in the weight of the beets and also of the leaves, a marked increase in the percentage of total nitrogen in the roots and likewise in the petioles, but not in the blades of the leaves. The percentage of proteid nitrogen was increased slightly in the roots and in the blades but not in the petioles. The percentage of nitric nitrogen was increased by two or three fold in the roots and by two and six fold in the petioles. This form of nitrogen had entirely disappeared from the blades of leaves from plants to which no nitrate had been applied by September 28, but was very abundant in this portion of plants to which nitrates had been applied up to October 12, only eight days before they were frozen. The large percentage of total nitrogen in the blades of the leaves, and the very large amount of proteid nitrogen, together with the fact that while the nitric nitrogen may be very abundant in the blades, it is always less so than in either the roots or the petioles, lead us to infer that the transformation of the nitrates into other forms, particularly into proteids takes place very largely in the blades. It has been shown by Prof. Remy[6] that the beet usually appropriates its nitrogen very largely in June and July and appropriates relatively small amounts in September and October.

THE EFFECTS OF NITROGEN ON MATURATION.

We find that in the beets to which no nitrates had been applied, the nitric nitrogen had entirely disappeared from the blades by September 28 and the usual signs of ripening, a change in the color of the leaves, i. e., a yellowing together with more or less flaccidity of the blades were observed by October 10. No signs of ripening were observed on the beets to which the nitrates had been applied, the blades were still green and turgid and we find them containing very marked quantities of nitric nitrogen, 0·012 and 0·014, against none in the blades of the ripening beets. The large amount of nitrates applied to these beets prolonged their vegetative period, and the dark-blue-green leaves were still discharging their function unimpared and were rich in nitric nitrogen.

DISCUSSION AND SUMMARY.

The analyses of the beet samples taken November 8 present the total effects of the defoliation upon the size and composition of the beets. The general results upon the yield of beets and sugar have already been stated as obtained from the plot returns which, in the case of the variety ER are more pronounced than is shown by the laboratory sample of 18 beets. The defoliated beets are smaller in size, poorer in sugar and also in dry substance than the normally developed beets, they are still much smaller than those grown with application of nitre and a little lower in both sugar and dry substance. The total nitrogen is decidedly less in the defoliated beets than in the normally developed beets while nitrate beets are very decidedly higher, this is also true of the total nitrogen in the juice expressed from the rasped pulp of the beet. The proteid nitrogen in the variety ER and in the press juice of both varieties is depressed but its ratio to the total is increased. The percentage of amino nitrogen is increased and also that of the nitric nitrogen. The defoliation has very radically affected the assimilation and metabolism of the nitrogen compounds in the beets: this is most marked in the case of the nitric nitrogen, the form in which the plant supposedly takes up its nitrogen supply. In the case of the variety ER the nitric nitrogen in the beet on September 1 was 0·01925, in the normally developed beet on November 8, 0·00827, in the defoliated beets on November 8, it was 0·01367. There is an actual depression in the percentage but it is not equal to that required to be proportional to the increase in the weight of the beets, in other words, there has been an increase in the amount of nitric nitrogen in these beets instead of a decrease as there was in the normally developed beets, and as there had been in those which had received an application of nitrates up to September 28. The total nitrogen in the beets of the variety ZR harvested November 8 is very low and the nitric nitrogen very high. In this variety we find the size of the beets depressed and the percentage of sugar no higher than it was on September 1 immediately prior to defoliation.

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[6] Blaetter fuer Zuckerruebenbau, 1909.

The amount of mineral matter taken up by the crop of defoliated beets is less than that taken up by the normally developed crop, but the ratio or percentage is scarcely disturbed at all. The most striking feature is perhaps the phosphoric acid which is the same in the normally developed and the defoliated beet, while it is decidedly depressed in the nitrate beets.

The complete defoliation of the beets on September 6 caused the production of smaller roots than were produced in the case of the same varieties with normal development. The roots were poorer in dry matter and in sugar than the normally developed beets. These results are in harmony with those previously observed. The effects upon the nitrogen in the beets was to suppress the total amount but it caused an increase in the nitric nitrogen present in the root while this form was materially reduced, 50 per cent., in the normally developed beet. The proteid nitrogen was also depressed showing that both the intake and assimilation of the nitrogen had been involved.

The effects of defoliation upon the ash constituents was proportional to the effect upon the size of the roots or crop and affected the composition of the ash but slightly, or not at all; the phosphoric acid is, perhaps, the best measure of this. The effects of the Chile-saltpetre are in part the same, but in the main are quite different. The similar effects are the depression of the percentages of dry substance and sugar in the roots. The dissimilar ones are an increase in the crop, both of roots and tops, an increase in the total nitrogen, a marked increase in the nitric nitrogen, the presence of larger amounts of proteid nitrogen with a low ratio to the total, an increase of the total ash, and a marked depression in the percentage of phosphoric acid. The function of the leaves and especially the blades seems to be concerned with the metabolism of the nitrogen taken up by the plant which is almost wholly suspended by complete defoliation, but the effect of nitrates is a radical derangement of the nutrition of the plant.

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SYSTEMATIC TESTING IN THE EVOLUTION OF MILL-PRACTICE.

By George E. Collins.

(President's Address, Annual Meeting, December 20, 1913.)

In relinquishing to my successor the position which I have now held for two years, I take this opportunity of expressing my appreciation of the loyal co-operation which I have received throughout from the Treasurer and Secretary, and from our colleagues on the Executive Committee. As you know, the Constitution of this Society places very great power in the hands of the Committee, which really controls its policy. For a number of years—ever since I have been in a position to judge—the Society has been most fortunate in selecting members of the Executive Committee who have devoted to its interests an amount of labor and care which the rest of the Society hardly realize. Above all, ours has been a most harmonious family; and so long as the Society preserves its traditional spirit of loyalty and trust, so long, I am confident, will it keep its place at the head of the scientific and technical activities of the State.

Financially, I feel that we have done well in holding our own during the last few years, which have been years of depression in the mining and metallurgical industries, in which a large proportion of our members are engaged. To the future, in this respect, I look forward with confidence. Not merely is it improbable that this condition of affairs in the industries which form the backbone of our State can continue indefinitely:—we have the best of reasons for believing that our finances will shortly be relieved of one heavy burden. We are assured of dignified and delightful quarters in the near future, in the new Museum building adjoining the State Capitol. These quarters will be ample for our present and future needs; and will enable us to continue the hospitable welcome which it has always been our pleasure to extend to kindred institutions. The Society's rooms are now in process of being partitioned off to suit our requirements, and while I regret that, like Moses of old, I shall not be able to lead you forth into this promised land after our thirty odd years of wandering, yet I can do the next best thing—remain enrolled as a humble private in the host which my successor will lead there. I feel sure that I voice the sentiments of every member of the Society, when I express our gratitude to the Board of Capitol Managers for this recognition of our Society, and to Messrs. Franklin Guiterman and Otto Mears for their unwearied efforts in our behalf.

In retiring from the Presidency I shall be far from leaving you, for whenever there is work to be done for the Society I hope to be of service. It is a great satisfaction to leave this gavel in hands which will be more competent than mine to wield it. I bespeak for my successor in office the same indulgent consideration, and the same loyal support, which you have always extended to me.

In selecting a subject for the annual Presidential address, it was perhaps inevitable that I should turn to the work which has occupied me during the past year. Of this, apart from the routine of administration, none has been more absorbing than the systematic testing which serves as a guide to the evolution of mill-practice.

Necessity for Regular and Continuous Testing.

Nothing can be farther from the truth than the common idea that a scheme of ore-treatment can be finally worked out in all its details prior to construction of a milling plant; or that such a scheme, once fixed, should need no reconsideration during the life of the mine it has to serve. This presupposes a homogeneous ore-deposit, unchanged scale and methods of working, and an amount of time and completeness of facilities for testing which are rarely available in practice.

In actual experience, uniform ore-bodies are uncommon. Perhaps the large low-grade dissemination and replacement ore-bodies approach nearest to uniformity; and even these appear so largely because they are worked on so great a scale that their mineralogical and physical differences are averaged. And whilst, in the case of some of these large low-grade mines, great sums were spent in testing and on experimental plants before the serious work of construction was commenced, nothing is more certain than that radical changes are yet possible. It is therefore no reflection on the skill of the metallurgist or the thoroughness of his preliminary work, if he finds it necessary to continue testing throughout the life of the plant.

I do not think it is generally realized to what an extent the millman's work is bound up with, and dependent on, that of the miner. The physical condition of the ore may be largely modified by methods of mining and handling, or by admixture of gangue in various forms. The difficult problems in milling which result from the presence of slime may be largely avoided by underground elimination of clay in stoping and passing through chutes. In many cases more soft mineral is slimed during stoping and dropping through chutes, than by the processes of crushing and grinding required during the concentration; and the proper solution of a milling problem may be found in the mine.

Again, careful selective mining of oxidized portions of ore-bodies, or of ore-streaks the physical or chemical properties of which introduce exceptional difficulties in the metallurgical scheme, may point the way to their elimination and separate treatment, by smelting or otherwise. The best technical and the best commercial results by no means always go hand-in-hand, and their frequent divergence is most apparent in the various forms of ore-dressing; which is not a final treatment, but merely a preparation for one.

For these and similar reasons I hold, as I have stated elsewhere, that while the technology of mining and metallurgy cover so wide a field that no man can ever hope to master all of it, and the specialist who confines his study and his work to one particular portion of the field has become an absolute necessity, if thoroughness in any direction is to be attained, yet the ultimate control and the ultimate decision (and with them also the ultimate responsibility), should rest on the all-round man,—the general practitioner, so to speak.

Constant testing is necessary, not merely to indicate ways in which the metallurgical saving of a plant may be improved, but also to control the working costs, and the relation of metallurgical to commercial saving. Furthermore, when the most suitable practice has been established, it is necessary to repeat similar tests at intervals, so as to ensure that no changed factor has crept into the practice, unknown to the management. Even apart from all these, there is a duty incumbent on every engineer to investigate the reasons for what he is doing and the results achieved by it; and last of all, the possibility that by constant study and record of his own results he may add to the general stock of knowledge, by the aid of which he may assist his fellows in solving similar problems more expeditiously.

UNSOUND CRITICISM OF PRACTICE IN SOME DISTRICTS.

My own experience commenced in districts where the prevalent milling practice has since been severely criticized, not without reason; although generally speaking the practice was sounder than the critics. Above all, they were districts where the exponents of the local methods were inarticulate, and had not learnt to express, nor had consciously thought out, the reasons for what they were doing. In Cornwall particularly, as I remember, some of the reasons we used to give for the methods we used were distinctly less rational than the methods themselves. Nor was this surprising, for the arguments represented the limitations or ignorance of the individual, whereas the practice had grown up during several generations out of the collective wisdom of an entire community. The realization of this has taught me to be chary of condemning local variations of practice; which at least are very likely to have become thoroughly adapted to local conditions.

In Cornwall we did very little testing; and insofar as we did any, we did not realize the importance of ensuring that only one condition was varied at a time. Our testing, in fact, was empirical, not inductive. This however was not especially characteristic of Cornwall; for the systematic experiments which we now-a-days use to guide and check our milling work were then, so far as I know, unheard of elsewhere.

In Gilpin County, and also in Cornwall, the actual saving, as expressed in percentages, was of less importance than the condition of the product. The tin-smelters in Cornwall penalized impure concentrates to such a degree that losses were often, and necessarily, heavy in the final cleaning process; for which reason, even where the physical nature of the ores was constant, a mere statement by percentage of saving would have been useless as a basis of comparison by which to gauge the relative efficiency of two dressing-plants. The failure to sufficiently realize this, or at all event to plainly state it, largely impairs the value of a recent elaborate paper by Horace G. Nicholls on the tin-dressing plant at the Geevor Mine, in Cornwall. So in Gilpin County, and in most other districts where the local metallurgy consists mainly in the preparation of the ore for treatment by smelting, the condition of the product matters more than the actual saving. At the Hidden Treasure mill, for years, the average gold content of the concentrate produced was under half-an-ounce. The finely-slimed mineral which was lost at this plant was usually lower in value than the coarser concentrate which was saved; for the gold which it originally contained had mostly been freed by fine crushing and removed by amalgamation. As the freight, treatment and handling charges amounted to approximately one-half the value, it is obvious that it did not—and does not now—pay to go to any extreme refinement of method by which a small additional saving of concentrate might be made. It is equally obvious that, in many cases, a small extra saving in the form of bullion, saleable to the United States Mint at $20.67 per ounce, was worth more to the producer than a much greater saving in the form of concentrate, saleable to custom smelting plants at an expense of from one-fourth to two-thirds of the value of the metals contained, and in which the gold was only paid for ultimately at the rate of $19 per ounce. This difference alone makes the commercial saving of gold better by 8% when contained in gold bullion than when the same amount of gold is contained in concentrate. It illustrates at once the argument in favor of the old Gilpin County method of milling as compared with concentration preliminary to smelting, for ores any considerable proportion of the gold in which is recoverable by amalgamation. Of course, the same argument is equally valid for cyanidation as against concentration.

Our Gilpin County tests were therefore based more on the relative market values of products obtained than on savings indicated by head and tailing assays; in other words, the tests were commercial rather than technical. I may illustrate the difference by giving some particulars of a fairly recent run made between different types of mill, for the purpose of indicating the preferable commercial treatment in various plants which happened to be available.

Over a hundred tons of ore was carefully divided, and an approximately equal quantity shipped to three separate mills, which I here designate as A, B and C. A and B represent various modifications of old-style Gilpin County stamp-mill practice, using deep discharge mortars, sliming as fine as possible, and subordinating saving by concentration to saving by amalgamation. Concentration is done by Gilpin County bumping-tables. C is a stamp-mill using low discharge, and classifying previous to concentration on stratifying tables.

In the case of A and B no head samples could be taken. Tailing samples were carefully taken by hand. In the case of C mill the ore was automatically sampled prior to crushing, and the tailing sampled by hand. In C both samples were taken by the mill force.

The results were as follows:

Percentage of saving, figured from products and waste assays.

	Gold	Silver
A	81·7	44·8
B	88·0	50·2
C	78·6	56·4
C (figured from crude and waste assays)	78·8	62·3

It will be seen here that the technical savings were very similar. The commercial saving, however, in the case of C was little more than one-half of that of the other mills, because of the smaller recovery in retorted gold, and the large proportion of the value in the concentrate swallowed up by freight and smelting charges.

No single test made in this way should be regarded as conclusive, because even if mortars were carefully cleaned out before treatment, which is rarely the case, a slight difference in the condition of amalgamated plates before the run was made, or in the closeness with which amalgam was removed from them after the run, might make more difference than any difference between two mills. The general result, for ores which are amenable to amalgamation at all, is however constant, and is moreover, obviously to be expected by any person who is sufficiently familiar with local conditions to realize the extreme effect of the cost of marketing products.

DISCORDANT RESULTS OBTAINED IN TESTING.

I do not know whether other engineers experience as much difficulty as I do in obtaining concordant results from their testing work. If so, they do not mention it in their published results. Having had the painful privilege in some cases of "cleaning up" after some of my confreres, I incline to suspect that the difference is sometimes one of puzzling out the discordant results on the one hand, and covering them up on the other.

There are innumerable chances for results to go wrong, either in the preparation of the samples, or in the assay office itself. I suppose that by the exercise of infinite care such discrepancies might be avoided, but so far I have not found any way of discovering or educating infallible men. Both from the point of view of general efficiency of staff and that of effective control of operation, I prefer to get a large amount of work through, and a large number of screen analyses and other tests made, even at the risk of having some inconsistent results included in the reports. Even with this, the tendency is to delay the completion of tests until they have become old history, and have to a large extent lost their value for the guidance of everyday operation.

I suppose everybody has had much the same experience; but it may be worth while, in order to illustrate the difficulties that crop up in this class of work, to give one example. See screen analysis (1).

Screen Analysis (1)

4 Ft. Hardinge Mill. Re-Grinding Jig Middling.

Fall from feed to discharge end, 1¾". *Speed* 30 R. P. M.
Solids =18·7%= 22·63 tons ore per 24 hours.
Water =81·3%=120·00 tons water per 24 hours.
Total tonnage 142·63 tons per 24 hours.

Feed						
Sample No.	*Mesh*	*%*	*Oz. Per Ton*		*Percentage*	
			Au.	*Ag.*	*Pb.*	*Zn.*
D-1	+ 20	46·34	·60	5·2	17·2	33·6
2	+ 40	12·20	·64	5·7	16·0	32·4
3	+ 60	7·32	·36	4·5	18·7	22·8
4	+120	8·54	·32	4·3	8·2	17·6
5	+200	14·63	·26	6·0	9·8	15·0
6	−200	10·87	·28	6·0	16·5	12·3
Average assay (calculated)			·48	5·3	15·2	26·2

Discharge						
Sample No.	*Mesh*	*%*	*Oz. Per Ton*		*Percentag*	
			Au.	*Ag.*	*Pb.*	*Z*
......	+ 20	......	.....	......	......	...
DD-0	+ 40	......	......	......	......	...
1	+ 60	2·44	Not enough for assay		7·5	23·
2	+100	12·19	1·00	9·0	5·7	22·
3	+200	34·15	1·24	5·4	11·0	26·
4	−200	51·22	·68	6·8	8·8	24·
Average assay (calculated)			·92	6·6	9·1	24·

PERCENTAGES OF TOTAL CONTENTS IN VARIOUS SIZED PRODUCTS.

Mesh	*Au.*	*Ag.*	*Pb.*	*Zn.*	*Mesh*	*Au.*	*Ag.*	*Pb.*	*Zn.*
+ 20	58·1	45·1	52·3	59·3	......	......	......	.....	......
+ 40	16·3	13·0	12·8	15·1	+ 40	......	......	.....	......
+ 60	5·5	6·2	9·0	6·4	+ 60	......	......	2·0	2·3
+100	5·7	6·9	4·6	5·7	+100	13·6	17·1	7·6	11·1
+200	7·9	16·4	9·4	8·4	+200	47·4	28·7	41·1	36·5
—200	6·4	12·3	11·9	5·1	—200	38·9	54·2	49·3	50·1

Here it will be observed that in the process of crushing, according to the screen analyses, the gold has been raised from 0·48 oz. to 0·92 oz. per ton, and the lead has dropped from 15·2 per cent. to 9·1 per cent.

There is nothing exceptional about the former; we have found that gold tends to accumulate in tube-mills, jig-beds, elevator sumps, etc.—in fact, everywhere in the plant where there is any opportunity for extreme classification to take place, and for exceptionally heavy particles to lodge. I shall return to this subject later.

The changes in the lead percentage are less to be expected *a priori.* But it illustrates the fact that the Hardinge mill (or other tube-mill) is a natural classifier, in which the heavier particles are retained longer, and ground finer, than the relatively lighter particles. As in this plant we always run a machine two shifts or more after making any change before taking samples, this should not lead to discordant results, if the feed were uniform. Uniformity of feed, however, is a most difficult thing to secure, when you have a mine yielding excessively variable ores, and a mill of moderate or small capacity. In this case we have a storage, with some natural mixing in the crushed-ore bins, of over five days' mill capacity; or an average of say two and one-half days' ore always on hand; yet uniformity of feed is an ideal which we have never attained.

Any change in grade or fineness, occurring within a couple of hours of the time when a test is being made, takes several hours before the discharge and feed are equalized; and meantime other changes may have occurred. In order to obtain concordant results from feed and discharge, therefore, it is desirable to continue a test for a week or more, samples of feed and discharge being taken at regular intervals throughout. As we cannot always wait so long for results or tie up a machine so long for purely experimental purposes, it is sometimes necessary to put up with data which we know before hand may be incorrect, in some direction.

The variations in assay serve as an index to probable corresponding variations in sizing. The sulphide minerals being so much softer than the gangue, it is certain that if there are unequal proportions of mineral in the feed and discharge, there will be corresponding variations in the proportions in the sizing, apart from those normally due to the work performed in the mill.

A similar discrepancy was observed in assays of feed and discharge from a 4-foot Hardinge mill which we used experimentally for re-grinding coarse sand tailing, with a view to its treatment on carpets and plates. This operation yielded a small quantity of amalgam, and some carpet washings assaying 2·75 ounces of gold per ton. Yet, during a period of several weeks, the daily samples of heads and tails showed, with I believe only two exceptions, a slightly higher gold content in the latter than in the former. The explanation, in this instance, must be that minute particles of gold and amalgam had lodged in the interstices of the silex lining, and collected in the enriched sands left in the mill before the test commenced, and gradually worked their way out in admixture with the pulp. Had we foreseen this difficulty, we might have avoided it by deferring this test until the mill had been newly lined, and then started it up with a load of new pebbles. We however supposed, not unnaturally, that as we intended continuing this test for a considerable period of time, any irregularities of the kind indicated would naturally adjust themselves after running a day or two.

CONICAL AND CYLINDRICAL TUBE MILLS.

It follows from the foregoing, I think, that no crushing appliance in which, as in the Hardinge and ordinary cylindrical tube-mill, classification takes place, can ever be a perfect non-sliming fine grinder.

The conical end of the Hardinge mill acts, to some extent, as a device to expedite continuous discharge, in much the same way as the device recently brought out by Chalmers and Williams for improving the discharge from a cylindrical tube-mill. The latter, which consists of a perforated diaphragm, between which and the discharge end is a series of adjustable shelves intended to raise the pulp to the center where it can flow out, may be more effective, but has not yet been tried out sufficiently to prove its value. The conical end of the Hardinge, whilst of limited efficiency, is simple and positive, and really works. One can obtain nearly as small a proportion of slime in a long tube-mill as in a Hardinge, by crowding the feed and using a large quantity of water; but apparently there is then a slight tendency for the discharge to contain still more oversize.

Mr. Hardinge's original contention that with his mill the weight of blow is automatically adjusted to suit the progressively finer particles of pulp as they pass from head to discharge end, and that owing to this automatic adjustment there is practically no necessity for return of oversize, is, according to our experience, not borne out by the facts. As in the case of the tube-mill, if you crowd the tonnage and increase the water sufficiently to obtain a granular product, you have to arrange for the return of a very considerable amount of oversize.

In various publications Hardinge has illustrated this supposed zonal action in his mill by cuts in which he superimposes on a picture of the conical mill, an outline of several gravity stamps, commencing with one of heavy weight and high drop, and progressively lessening to one of small weight and low drop at the end; the stamps being supposed to represent the force of blow struck by the pebbles in the corresponding stages of the Hardinge mill as you pass from feed to discharge end.

This is, however, largely a fallacy. It is true that the size of pebbles is automatically graded, to some extent, and obviously the force of blow struck would be thereby lessened. But the peripheral speed is at the same time lessened to such a degree that near the discharge end the pebbles merely slide on one another without cascading, so that there is no crushing action worth mentioning, and what actually occurs is a slight process of abrasion, which is just what we want to avoid. In fact, in comparing the work of the Hardinge with that of the tube-mill, according to our experience, it is pretty much a question of relative first cost and operating expense. We have at Romley one 3½-foot by 16-foot Gates tube-mill, two 6-foot by 22-inch Hardinge mills, and one 4-foot by 22-inch Hardinge. We find that the capacities of the tube-mill and that of one 6-foot Hardinge, using the same feed, are almost identical; and the cost of the Hardinge was about 20 per cent greater. As to power consumption, we have no means of measuring. The Hardinge uses more pebbles, and has to be relined oftener.

SEPARATE REGRINDING OF SAND TAILING AND MINERALIZED MIDDLING.

In the Mary Murphy mill, we have hitherto used the 6-foot Hardinges and the tube-mill to do the same work on the same feed. As the result of our experiments, we expect hereafter to do the bulk of the regrinding with the Hardinges, using the tube-mill to re-grind the coarse sands from the tables. The 4-foot Hardinge was intended, and is still used, to grind the heavily mineralized middling from jigs, the idea being that this material required for proper granulation a lighter pebble and less total weight of pebbles; furthermore, that it should be more satisfactorily ground by itself, unmixed with the particles of hard, tough quartz and rhodonite of the gangue. I now doubt very much if this latter hypothesis was correct;

and incline to suspect that one effect of the hard gangue particles may be to protect the soft grains of mineral, in some degree, from sliming after they have once been crushed fine enough. What, however, is certain is that crushing the jig-middling in a separate machine enables us to realize precisely what result we are actually obtaining. This is indicated by the color of the discharge, which looks a good deal like ink, and by the screen analyses, which show anywhere from 30 to 70 per cent of —200 size, averaging in metallic contents 65% of the lead and 51% of the total zinc.

The sizes below 100-mesh contain nearly all the lead and most of the zinc in the feed: (93% of the total lead and 85% of the total zinc.)

As stated above, by greatly crowding the feed we are able to lessen the proportion of unduly ground material, to a very large extent. This is well shown by the accompanying screen analysis (2), which shows only 12·1% of —200-mesh material.

SCREEN ANALYSIS (2)

4 FT. HARDINGE MILL. RE-GRINDING JIG MIDDLING.

Fall from feed to discharge end 1¼″. *Speed* 28 R. P. M.
Solids =32·4%= 34·6 tons per 24 hours.
Water=67·6%= 72·0 tons per 24 hours.
Total tonnage 106·6 tons per 24 hours.
Pebble Load, 0·9 tons. Main mill treating 140 tons per 24 hours at the time when samples were taken.

FEED						DISCHARGE					
Mesh	*%*	*Au.*	*Ag.*	*Pb.*	*Zn.*	*Mesh*	*%*	*Au.*	*Ag.*	*Pb.*	*Zn.*
On 10	32·6	·12	2·1	6·8	11·0	On 10	3·0	·22	2·9	4·4	9·5
ʻʻ 14	17·0	·20	1·9	4·7	11·3	ʻʻ 14	4·2	·18	2·4	4·4	10·0
ʻʻ 20	14·5	·18	2·0	4·1	10·1	ʻʻ 20	7·2	1·24	2·3	3·8	9·4
ʻʻ 28	11·6	·21	2·3	4·1	10·3	ʻʻ 28	10·2	·56	2·2	3·5	9·2
ʻʻ 35	8·3	·14	2·3	4·4	10·7	ʻʻ 35	12·1	·42	2·1	3·5	9·0
ʻʻ 48	4·7	·11	1·9	3·1	11·3	ʻʻ 48	12·6	·42	2·6	3·8	10·6
ʻʻ 65	3·1	·14	2·2	2·5	12·3	ʻʻ 65	11·1	·44	2·9	6·3	14·1
ʻʻ 100	2·9	·12	1·8	2·3	11·7	ʻʻ 100	10·7	·44	3·2	7·4	15·5
ʻʻ 150	2·4	·09	1·7	1·7	10·0	ʻʻ 150	9·6	·40	2·9	9·6	16·1
ʻʻ 200	1·1	·08	2·0	2·5	11·7	ʻʻ 200	7·2	·21	3·7	13·4	15·1
hrough 200	1·8	·12	3·9	8·9	13·0	Through 200	12·1	·18	4·4	15·2	12·5
alculated Average Assay		·15	2·1	5·0	10·9	Calculated Average Assay		·44	2.9	7·1	12·1

(Tyler standard testing screens used in above test.)

The use of this method is, however, not always possible; for in a small plant, or even one of moderate size, the tonnage available of any given material is limited, and is fixed by the relation between various factors due to other machines; and by no means always corresponds with the sizes of machines commercially manufactured. And this again is a decided disadvantage, for small plants, of the entire tube-mill class of machine, in which the character of the product as well as the cost of operation is modified by the quantity of feed.

Moreover, in the example shown, the lessened quantity of undersize is obtained at the expense of producing a prohibitive proportion of oversize (49·3 per cent).

To show the enormous influence on product of differing quantities of feed, I reproduce screen analysis (3), which shows that by reducing the feed to 14 tons, keeping the other factors approximately constant, the result was entire elimination of oversize, but the increase of —200 mesh product to the enormous figure of 72·8 per cent. Unfortunately, there was some change in the feed, that in No. 3 containing more mineral, and therefore being softer. Owing to the extreme variability in quantity and character of the side discharge from the jigs, it is not possible to maintain uniformity in the material to be reground.

Screen-analysis (2) also illustrates in a rather striking way the tendency for the total gold in discharge to exceed that in the feed. There were 11 screen sizes in each case, and in all but one size, when feed and discharge ran about the same, the gold was far higher in the discharge. The average gold indicated by the assays in the feed was 0·15 oz.; and in the discharge 0·44 oz. Substituting for the highest assay in the discharge the average of the assays on the adjacent sizes, the average of the discharge is reduced to 0·37 oz., or two and one-half times the average of the feed.

We are now installing a pair of rolls, to be set close, to re-crush these soft middlings, and shall hold the 4-foot Hardinge in reserve, for use when some of the other machines are out of commission for repairs.

SCREEN ANALYSIS (3)

4 FT. HARDINGE MILL. RE-GRINDING JIG MIDDLING.

Fall from feed to discharge end 1¼". *Speed* 28 R. P. M.
Solids =35%= 14·04 tons per 24 hours. Mill running two shifts
Water=65%= 26·07 tons per 24 hours. before samples were taken.
Total tonnage 40·11 tons per 24 hours.

Pebble Load, 0·8 tons. Silex lining. Main mill treating 150 tons per 24 hours at the time when samples were taken.

FEED						DISCHARGE					
Mesh	%	*Au.*	*Ag.*	*Pb.*	*Zn.*	*Mesh*	%	*Au.*	*Ag.*	*Pb.*	*Zn.*
On 10	66·0	·40	6·4	22·0	23·5	On 10	......	......	......	......	......
" 14	16·0	·22	7·6	16·2	22·8	" 14	......	......	......	......	......
" 20	9·9	·26	5·1	16·2	21.7	" 20	......	......	......	......	......
" 28	4·2	·34	5·9	19·0	19·0	" 28	......	......	.....	......	......
" 35	......	not enough for assay				" 35	......	......	.....	......	.....
" 48	......					" 48	4·5	2·80	7·4	6·8	14·6
" 65	2·0	combined with 100 mesh				" 65					
" 100	1·9	·38	5·4	19·0	14·0	" 100					
" 150	....	......	.....	......	......	" 150	9·1	1·62	5·2	11·6	17·4
" 200		......	......	......	.....	" 200	13·6	·82	5·7	21·2	17·3
Through 200		......	......	......	......	Through 200	72·8	·32	6·5	32·2	14·0
Calculated Average Assay		·35	6·4	20·2	22·6	**Calculated Average Assay**		·62	6·3	27·7	14·8

PERCENTAGES OF TOTAL CONTENTS IN VARIOUS SIZED PRODUCTS.

FEED					DISCHARGE				
Mesh	*Au.*	*Ag.*	*Pb.*	*Zn.*	*Mesh*	*Au.*	*Ag.*	*Pb.*	*Zn.*
+10	74·6	66·0	71·6	68·5	+48 to +100	20·4	5·3	1·1	4·4
+14	9·9	19·0	12·8	16·1	+150	23·9	7·5	3.8	10·7
+20	7·3	7·9	7·9	9·5	+200	18·0	12·3	10·4	15·9
+28	4·0	3·8	4·0	3·5	−200	37·7	75·0	84·7	68·9
+35 and below	4·2	3·3	3·7	2·4					
	100·0								

VALUE OF SCREEN ANALYSES.

I have always been disinclined to attach overmuch weight to the details of screen analyses, excepting as to their general trend. If we take two identical samples, and compare duplicate screen analyses on them, made by different individuals, or even by the same person, we usually find wide variations in the results. Such differences indeed we may expect, in view of the rectangular apertures employed, and the varied forms of the particles to be screened. When a particle is, in every section but one, larger than the screen aperture, and in that one section just small enough to pass through the aperture, but only if rightly oriented, it is clear that particle and aperture may be brought into contact perhaps a hundred times before it will pass, and in the meantime sharp edges of many other particles, which at first would not have passed through, may have become worn down sufficiently to enable them to pass.

The difference between screen analyses performed wet and dry is well known.

Some of the spotty gold assays which have crept into our screen analyses may perhaps be due to the alternate use, for such tests, on rich and poor material, of the same nests of screens. In the finer sizes, a considerable proportion of the apertures becomes blinded, and if there are small particles of gold included in the material thus held in the screen, they may become dislodged when screening subsequent samples, so introducing erratic assays into the latter. As far as possible, however, we guard against this contingency by using a different set of testing screens for high-grade and low-grade mill work.

I referred above to occurrences of free coarse gold in the mill. So far as I can learn, during the entire 35 years of the mine's history, no specimen showing free gold has ever been seen. Yet the existence of pockets of free gold has been inferred from the occasional erratic bunches of extremely rich ore encountered, and the unusually spotty assays, which suggested that the rich ore could not exist in the form of telluride or other friable material.

At intervals, in the mill, we have found sudden evidences of coarse gold. The gold ordinarily caught on the plates is fine; by dissolving the amalgam with nitric acid, 82% was found to pass a 100-mesh screen. Its fineness, moveover, averages only 550. The other kind of gold is of about 650 fineness, and coarse—nearly all of it over 20-mesh. It is mostly caught on the carpets used below the plates, and on the first few riffles of the Card tables which are fed from the two first spigots of the classifier line. Both these products are taken direct in pipes to a grinding pan of arastra type, with a bottom paved with silex bricks, and a stone drag, where they are ground continuously with quicksilver; the amalgam being cleaned out daily through a spout in the bottom, and the overflow settled and added to the high-grade concentrate. In this way we avoid difficulty in sampling and selling unnecessarily spotty concentrates, and furthermore are able to keep slightly better control of the gold contents throughout the system.

At times on the jig-beds, we have been able to sort out quite a number of pounds of metallic particles, attached sometimes to quartz and sulphide minerals. These range in size from 2 mm.—the mesh of the jig-screens used—up to 1-3 inch. One or two such nuggets found in the trommels were over ½-inch in diameter, and consisted almost entirely of gold of about 670 fineness.

METHODS OF CALCULATING RECOVERY.

There has been a great deal of discussion in the technical press during the past year with reference to methods of calculating rates of extraction in mill work. We have the partisans of the method of calculating from weights and assays of tailing, or from assays entirely, excluding weights, together with products, on the one hand, and on the other hand, those who insist on the necessity for sampling heads, which usually requires a sampling plant. To me it seems a question to be decided on the merits of each individual case. Poor samples of mill feed are worth very little; and accurate sampling usually adds materially to costs of construction and operation. Samples of tailing can usually be obtained with relative accuracy; and products must be accurately sampled for purposes of sale, so that their accurate determination is chargeable, not to cost of mill operation, but to cost of realizing products. Where only one or two products are to be marketed, it seems to me that the method of calculating heads is admissable; the objection to its use comes with more validity from the general management, which may require the independent check on the mine work which is afforded by actual sampling of the mill heads.

Where on the other hand we have many metals to be recovered, and many products to be made, which are marketed at irregular intervals, samples of headings become almost indispensable in order to control the daily work. Even with this help, in the case of the plant which I have in mind, the locked-up material in sumps, mills, etc., so affects the daily tailing that (especially as to gold content) it does not always correspond with the daily feed. This is strikingly illustrated by the fact that, when we have a daily feed which happens to run up in gold, the tailing often shows no increase; but it does so for several days thereafter.

In the course of the discussion above referred to, Mr. W. S. Welton objected to the use of tailing assays in figuring savings, for the reason that the water decanted from the tailing sample "invariably contains higher values than the material which settles and accordingly carries away a large percentage in suspension." To quote from his article in the Engineering and Mining Journal of July 12, 1913: "Under working conditions, it is impossible to ascertain directly the real value of the tailing.

"From the moment concentration commences, the water made use of carries off mineral of value, and this continues all through the process. The amount of floating mineral will vary with the fineness of division of the particles, degree of concentration, amount of water used, and inclination of the tables, or with the rapidity of concentration. The effect of these circumstances is to cause the settled tailing to be invariably of lower assay value than if there was no float."

A little further on Mr. Welton states that "to estimate the extraction" it is "clearly necessary to know either the correct value of the mill feed or of the tailing;" and in view of the difficulty he considers to exist in sampling the tailing, recommends dependence on sampling the feed.

This contention was supported by a number of assays taken in the course of some concentration tests on silver ores. It would, however, be difficult to find a more striking case of the fallacies which may result when one argues from the particular case to the general. In the first place, whilst the suspended slime tailing from concentration is usually of higher assay than the sand, it is not "invariably" or necessarily so—in my own experience I have found several instances where the contrary was true. In the second place, if proper time is allowed for settling, and lime or other aid to settling made use of, the loss in suspension is usually small. Finally, as the ease of taking correct samples increases with the fineness of the particles, there is no excuse for not getting accurate samples of the water, plus whatever matter it may hold in suspension; nor is there any insuperable difficulty in evaporating the entire sample to dryness, water and all. What we do in practice is to settle the sample with lime, decant the clear water, and evaporate the rest to dryness. But as a further precaution, we occasionally save the whole of the water decanted, evaporate it and assay the residue. In the case of the Mary Murphy, this is much richer than the sand tailing; but the proportion of solid is so small that it makes little difference.

The last time this test was made the proportion of solid in the decanted water was 0·025%, which assayed:

Gold, trace; silver, 1·4 oz.; lead, 4%; zinc, 18·7%.

The weight of water is about 15 times that of the dry pulp, so that it is easily seen that the loss suspended in the water is negligible. I think every mill should make such tests at intervals, in order to guard against a peculiarly insidious form of loss; but in my experience it is rarely the case that the inaccuracy in tailing samples caused thereby is of any moment, assuming that the tailing is properly settled.

There are three essentially different ways in which to calculate mill savings: from head and tailing, from head and products, and from products and tailing. In simple mills, recovering but one or two kinds of product, it is a good plan to calculate the saving in all of these three ways, and compare the results. This is an excellent way of testing the accuracy of the sampling all through; and personally, although my own experience has generally been that I was quite unable to obtain the same result with the different methods, yet I have always thought it a very admirable plan. Nothing calls your attention so forcibly and at the same time so promptly to the weak points of your sampling work. Even with the most complicated mill systems, it is well to take stock in this way at intervals.

Where owing to expense or other reasons only part of the sampling can be done automatically, it is clear that the tailing should be selected for this; because, after all, what primarily concerns the mill man is what he is losing, and how far it will pay him to follow it. The products are less essential to watch, because the cash account directs attention to them in the most forcible way possible; and also because the methods of sale usually ensure systematic sampling and record, even without conscious attention on the part of the operator.

It is frequently forgotten that to calculate the percentage of saving is, in itself, of no value. What we really want to know is, what is contained in the material that we are losing, and to what extent is it worth while to pursue it farther. If we are throwing away $10 per ton from a $40 ore, we are obviously losing what, under most conditions, it will pay to save. If we are losing $1 from $4 ore, it will rarely pay to attempt to recover it. Yet the percentage of saving is the same in each case.

Worthlessness of Many Published Data.

Whatever convenience of arrangement, whatever apparent completeness of flow-sheet a dressing-plant may possess, if at the end the waste products are not led to a single channel where an automatic sample can be taken, we are justified in regarding it with suspicion, and in declining to receive with confidence any claims advanced as to the extraction made. There may be commercial reasons why the losses from a milling plant should not be published. I have even known cases where there were valid reasons why such determinations should not be systematically made. It should, however, be considered the unpardonable sin to pretend that they exist when they do not; and to publish to the world as technical data of scientific value what are merely efforts to advertise men or plants, on the strength of partial misrepresentative figures. Nearly one-half of published accounts of mining costs and of metallurgical savings are unreliable; and are in fact advertising matter, not reports. The very first time that the margin of error happens to operate both ways, so as to enable him to figure out a high saving, our budding metallurgist breaks out into print, or hands his "data" to somebody else who does the same service for him. Directly a new plant attains its full tonnage, and before the inevitable budget for repairs, supplemental construction and depreciation begins to be felt, similar data of "costs," equally misleading, are published. Thus the columns of our technical journals are filled; and the great ocean of human misinformation expands. Other writers quote in good faith from such articles, so that in the end we all become loaded up with a great deal of knowledge of things that are not so. What we need is a board of censors, an "International Brotherhood of Knockers," who will devote themselves to the task of puncturing balloons and disentangling knots. The members of this noble band should pledge themselves to contradict misstatements whenever found, to expose absurd pretensions, to point out fallacies. The residuum of real information would occupy one-tenth of the present bulk; and there might be some prospect of the ordinary person keeping up with the march of achievement.

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